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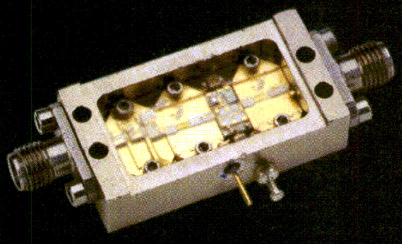

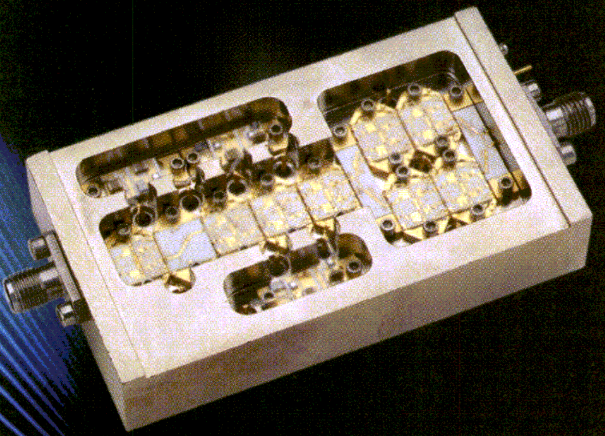

ULTRA BROAD BAND

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 Curren 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 Curren 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 Curren 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 Curren 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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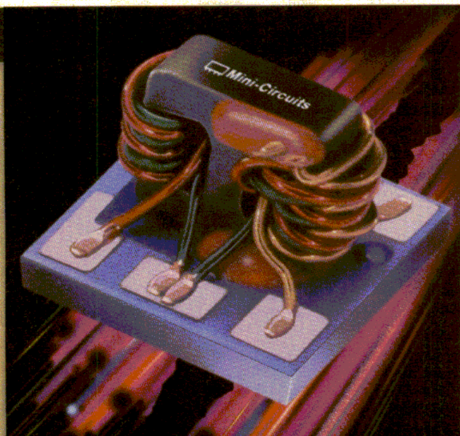

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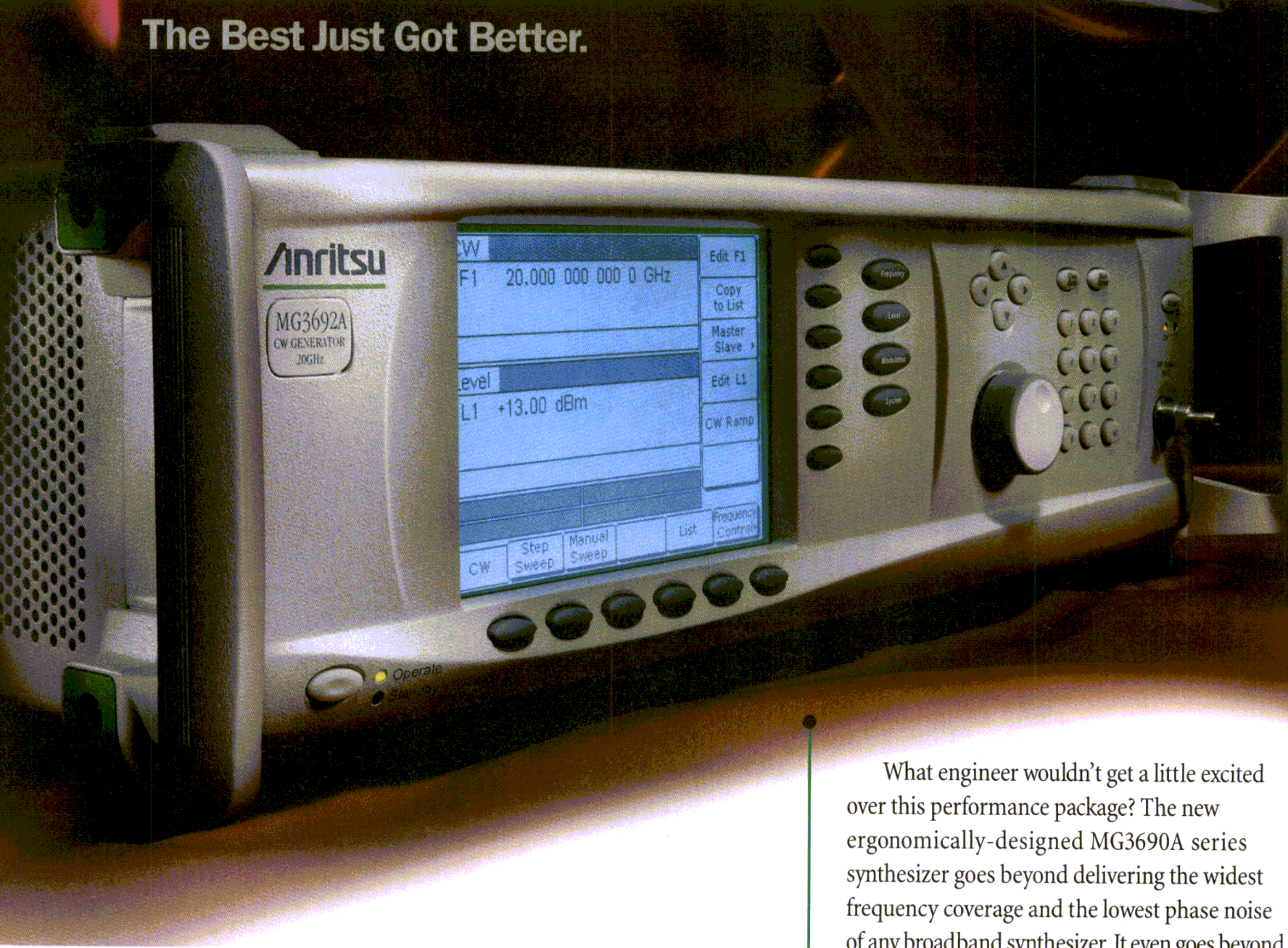

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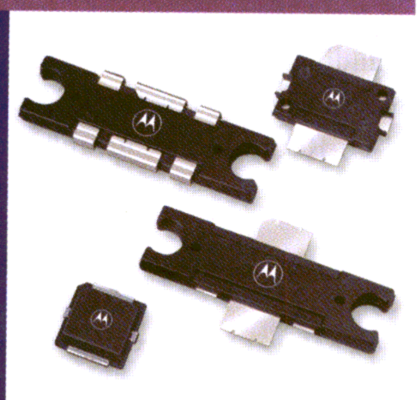
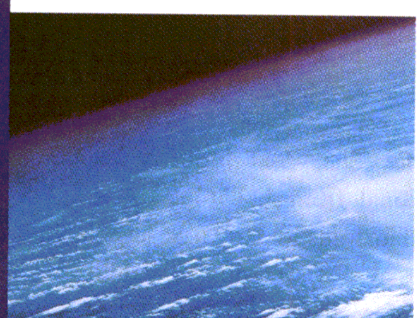
Motorola introduces two new families of RF LDMOS high power transistors in RF power plastic packages for cellular and land mobile applications.



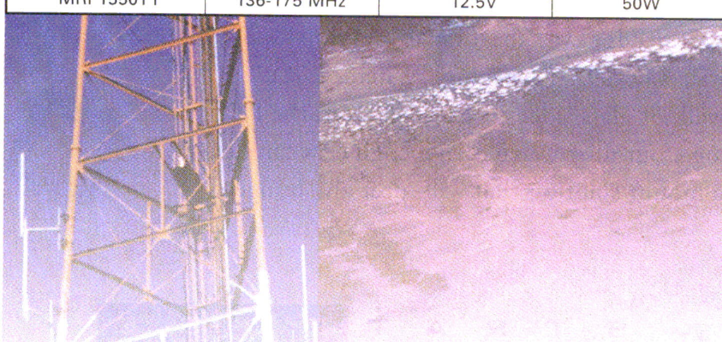
The MRF9000M series is optimized for 1.0GHz base station applications and is housed in the TO-270 and TO-272 RF power plastic packages. With guaranteed ruggedness and integrated ESD protection, this new 900MHz plastic product line will simplify handling and reduce the overall cost of cellular amplifier production.

DigitalDNA™ from Motorola



For land mobile applications, Motorola developed the MRF1500 family. Designed for broadband commercial and industrial applications at frequencies up to 520 MHz, the high gain and broadband performance of this family make the devices ideal for large-signal, common source amplifier applications.

Device	Frequency	Operating Voltage	Output Power	Gain (Typ)	Eff. (Typ)	Package
MRF9030MR1	1.0 GHz	26V	30W (PEP)	19 dB	41% (two-tone)	TO-270
MRF9030MBR1	1.0 GHz	26V	30W (PEP)	19 dB	41% (two-tone)	TO-272
MRF9045MR1	1.0 GHz	28V	45W (PEP)	18.5 dB	41% (two-tone)	TO-270
MRF9045MBR1	1.0 GHz	28V	45W (PEP)	18.5 dB	41% (two-tone)	TO-272
MRF9060MR1	1.0 GHz	26V	60W (PEP)	17.7 dB	39% (two-tone)	TO-270
MRF9060MBR1	1.0 GHz	26V	60W (PEP)	17.7 dB	39% (two-tone)	TO-272
MRF1511T1	136-175 MHz	7.5V	8W	11.5 dB	55%	PLD1.5
MRF1517T1	430-520 MHz	7.5V	8W	11 dB	55%	PLD1.5
MRF1513T1	400-520 MHz	7.5/12.5V	3W	11 dB	55%	PLD1.5
MRF1518T1	400-520 MHz	12.5V	8W	11 dB	55%	PLD1.5
MRF1535T1	400-520 MHz	12.5V	35W	10 dB (min)	50% (min)	TO-272
MRF1550T1	136-175 MHz	12.5V	50W	10 dB (min)	50% (min)	TO-272



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Article Corrections

▶▶THERE ARE SEVERAL corrections that I would like to make to my article ("Design A Tunable Resonant-Tank Circuit, Part 1," p. 69) in the May issue:

• On page 70, in the first paragraph after Eq. 10, the text reads, ". . .and the varactor package capacitance." The word "inductor" should replace the word "varactor."

• In the second full paragraph on page 72, the text reads, "The ESL reflects series and parallel resistance . . ." Please replace "ESL" with "ESR."

• On page 74, in the first paragraph after Eq. 19, the text reads, "$Q_L >> \omega^2 L_C Q_C$." It should read, "$Q_L >> \omega^2 L C Q_C$."

• On page 78, in the paragraph after Eq. 31, a line was deleted. The line should read, "Here, H is substrate thickness (mm). The formula can be used for $w/H > 0.05$." This is important information, and it is helpful to keep this line of text.

• On page 85, in the first paragraph after Eq. 53, the text reads, "When using Eq. 5, the same . . ." Please replace "Eq. 5" with "Eq. 53."

Sam Belkin
CTO
Euroscience

Editor's Note:
Please see part 2 of Mr. Belkin's article beginning on p. 73 of this issue.

E-mail Mistake

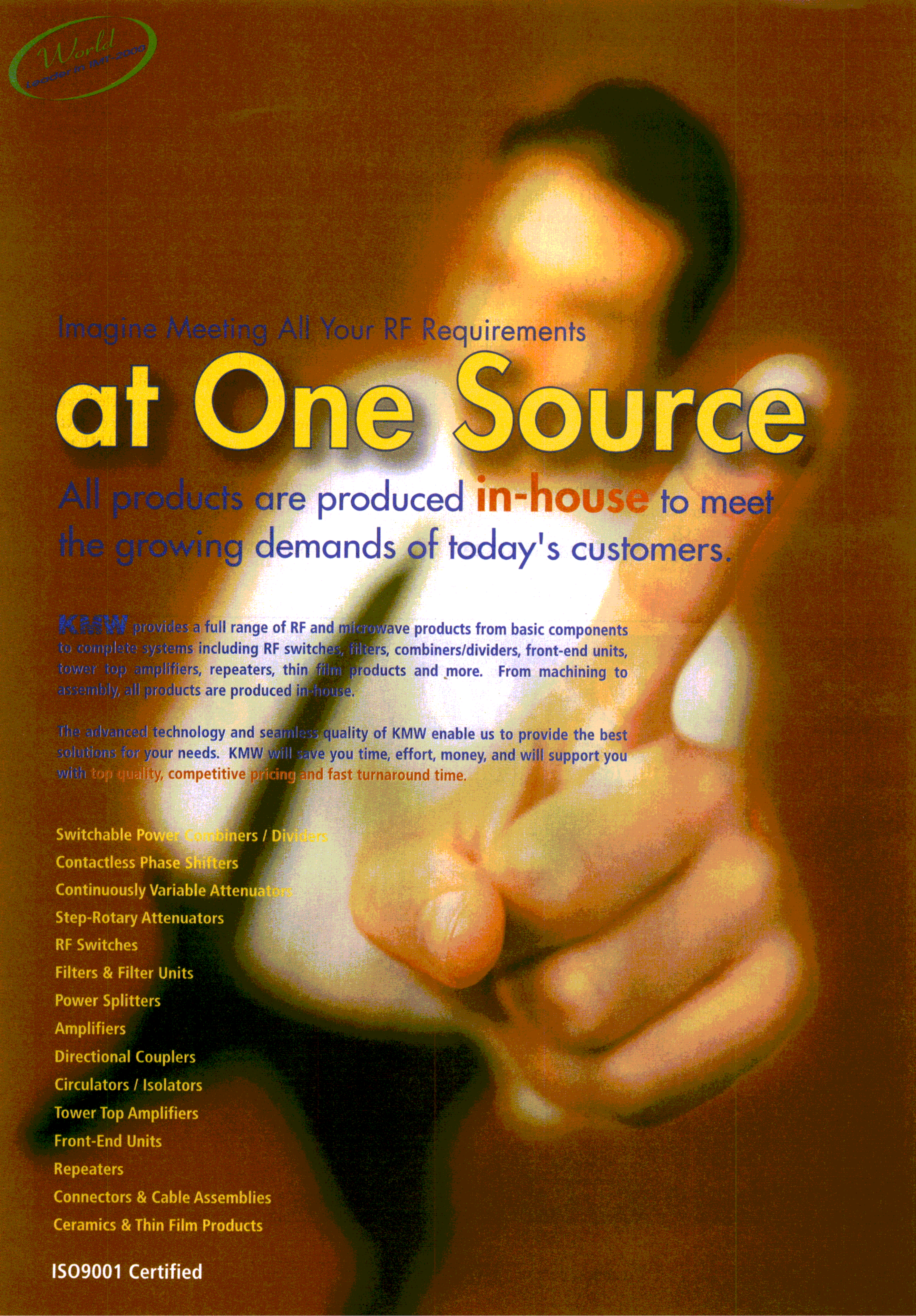
▶▶SEVERAL MONTHS AGO, Alan ("Pete") Conrad of *Microwaves & RF* contacted me about material for your Software Solutions section. The December 2000 article "CD-ROM Encyclopedia Sorts Global Radars" (p. 162) discussed my International Radar Directory (IRD).

Several people who saw the article have been highly complementary about it to me. It is undoubtedly the best review of IRD that I have ever seen. It was concise, but very complete. Mr. Conrad did an outstanding job, however, there was one mistake.

While my name, address, telephone number, and FAX number are correct, my e-mail address is not. The URL for my web page is: www.eglinaoc.org/ECCM.html. My personal e-mail address is radarslj@ieee.org.

Thank you for clarifying this for your readers.

Stephen Johnson
Huntsville, AL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Final Musings On The 2001 MTT-S

Phoenix was hot, as expected. But the city and its Phoenix Civic Plaza turned out to be quite a hospitable site for the recent IEEE/International Microwave Theory & Techniques Symposium (MTT-S) conference and exhibition (May 20-25, 2001). Those attending the technical sessions were not disappointed by the full breadth of technologies offered in the presentations. And the exhibit floor was particularly lively, with many exhibitors reporting having visited with many of their key customers and, in some cases, meeting with some potentially new customers.

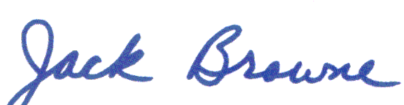
Given the general economic downturn and softening of the business environment, the mood of exhibitors and attendees at the 2001 MTT-S was surprisingly upbeat.

Phoenix in summer or even approaching summer is probably not the first choice for a show site among MTT-S attendees would make for a show site. But the Phoenix Civic Plaza is well-suited to an event such as this, with a generous number of meeting rooms for technical presentations and workshops and a location in close proximity to major thoroughfares for ease of travel. Even the odd corridor-like shape of the show floor created a flow of visitors through the entire exhibition area.

Concerning technology trends, the firm footing that computer-aided engineering (CAE) has established in this field was apparent from the number of technical papers on modeling and simulation and the number and size of the exhibitor booths managed by CAE software suppliers. Demonstration programs and student editions were available at many of these booths, and Sonnet Software (Liverpool, NY) even gave away Sonnet Lite software, a scaled-down, but nonetheless workable, version of their powerful planar electromagnetic (EM)-simulation software (see p. 129 for a review).

It was the first MTT-S where microelectromechanical systems (MEMS) technology was in evidence on the show floor. Several technical sessions addressed the topic, but some companies also had working products. For example, MEMSCAP, Inc. (Grenoble, France and Oakland, CA) displayed lines of variable capacitors and switches, while Dow-Key Microwave (Ventura, CA) demonstrated the operation of a high-speed microwave switch rated for millions of switching operations without degradation in performance.

Given the general economic downturn and softening of the business environment for many firms, the mood of exhibitors and attendees at the 2001 MTT-S was surprisingly upbeat. Most visitors left with a sense of optimism, feeling that economic recovery might some sooner than expected.



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Sessions are selected based on content originality, quality and timeliness. We do not imitate programs found at other conferences. If you are planning to present the same topic within the next 12 months, please indicate where so your program can be adjusted appropriately. We do not accept canned topics, or overtly commercial content. Each session must be one-of-a-kind and intended to inform, not sell attendees. All submitted material becomes the property of Penton Media, Inc.

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To be considered as a speaker, please submit the following information:

1. Your name, title, company or organization, address, phone, fax and email address.
2. A short professional biography (50 words maximum).
3. Proposed session title and a 150-word abstract. This material must be included or your submission will not be considered.

   Please indicate what type of session you are proposing. We offer three types of sessions at the Wireless/Portable Symposium & Exhibition:

   - Paper Presentation Session: Led by a "Session Chair" and includes a number of papers on a general theme. Each speaker/author makes a 20-30 minute presentation based on their paper.
   - Mini-Tutorial "Expert" Session: Presented by an expert instructor on one concise topic, a case study, a narrow discipline, or "tips and tricks". 1 to 1.5 hours in length.
   - Full-Day Workshop Tutorial Session: 1 or 2 day session presented by an expert instructor.
4. If you will be speaking elsewhere within the next twelve months, please indicate where.

Submit your session proposal by September 7, 2001 to Betsy Tapp, Conference Manager, via fax 201-393-6297 or e-mail btapp@penton.com.

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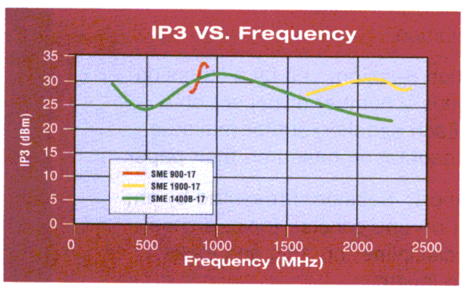

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SME 1400B-10	1-2200	1-2200	1-2000	+10	+6	+19	6.5	30
SME 1400B-13	1-2200	1-2200	1-2000	+13	+9	+22	6.5	30
SME 1400B-17	1-2200	1-2200	1-2000	+17	+13	+27	6.5	30
SME 1900-17	1600-2400	1400-2390	10-250	+17	+14	+29	7.4	26

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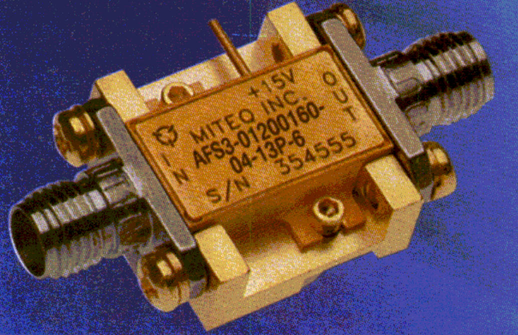
AMPLIFIERS



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.

Power-Semiconductor Industry Remains Strong Despite Tech Market Collapse

OYSTER BAY, NY—The abysmal performance of the tech market during the first quarter of the year has many believing that they should steer clear of tech stocks, but the power-semiconductor market continues to perform quite well, according to findings of a recent study from Allied Business Intelligence, Inc. (ABI). The study, which is entitled "Wireless Power Devices: Transistors, ICs and Power Modules," forecasts that the market will grow from $2.9 billion this year to $8.4 billion in 2006 **(see table)**.

Although the narrowband cellular infrastructure/handset arena represents the most financially attractive market for power semiconductors, other markets are poised for substantial growth. Broadband wireless access and industrial-scientific-medical (ISM) band applications merit attention as well. The proliferation of second-generation/third-generation (2G/3G) systems and broadband wireless-local-loop (WLL) platforms will propel this market forward.

"The natural evolution from voice to data has inspired profound changes in the cellular-handset and infrastructure market—crucial areas for GaAs transistors, MMICs, power modules, and silicon power transistors," says Natalie Amiama, an ABI analyst and the report's author. "3G will beget an era of integration as new handset manufacturers, mainly third-tier players, lack RF experience, and as tier-one manufacturers slash product life cycles. These changes will renew the popularity of power modules, and will force component suppliers to adopt alternate strategies."

RF Power Devices World Serviceable Available Market: 2001 to 2006

YEAR	VALUE (Millions of dollars)
2001	2858
2002	3617
2003	4453
2004	5503
2005	6763
2006	8350
CAAG	**24 percent**

*Includes silicon power transistors, GaAs PA MMICs, and GaAs power transistors.
Source: Allied Business Intelligence, Inc.

Industry-First CDMA 1xEV-DV Solution Is Successfully Demonstrated

LAS VEGAS, NV—Motorola, Inc.'s Global Telecom Solutions Sector (GTSS) successfully transmitted the world's first live video over its own third-generation (3G) code-division-multiple-access (CDMA) 1xEV-DV solution in its Arlington Heights, IL lab.

A number of wireless telephone operators and competing infrastructure vendors from around the world viewed the special demonstration in Motorola's advanced technology development labs earlier this year. The demonstration validates the air interference of 1xEV-DV and high-speed data throughputs of 4.8 Mb/s over the CDMA RF channel. It is the first time in the mobile wireless industry that a 64QAM scheme was achieved over a CDMA RF channel. This is significant because it demonstrated the potential to increase the 1xRTT data rate from its initial capability of 144 kb/s to a potential of almost 5 Mb/s with enhancements to the CDMA 1x air interface.

Motorola's 1xEV-DV solution, if adopted, enables real-time voice, data, and multimedia services on existing cdma2000 networks allowing end users to browse the Internet from a personal computer (PC) or access e-mail while mobile. Wireless carriers using CDMA technology will release the initial 3G enhancements to the technology later this year.


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EDA Pioneer Celebrates Twentieth Anniversary

WILSONVILLE, OR—Mentor Graphics, a pioneer in the electronic-design-automation (EDA) industry, celebrated their twentieth year of operation in April.

The EDA industry creates the software tools that allow engineers to create better and faster semiconductor chips and systems. This technology is used to design the most complex system-on-a-chip (SoC) semiconductors, printed-circuit boards (PCBs), and systems. Originally considered computer-aided engineering (CAE), EDA has evolved to become the fuel of today's rapid technology growth.

"Twenty years ago, our customers were designing chips for the first generation of Walkman portable stereos," states Walden C. Rhines, CEO and chairman of Mentor Graphics. "Today, engineers use our latest tools to design products such as ultra-fast microprocessors, or to deliver the chips for the next generation of cellular phones. EDA is what enables the newest features such as extended battery life, smaller size, lowered cost, increased performance, speed, and reliability."

Founded in 1981 by three former employees of Tektronix, Mentor has grown to be the second-largest Oregon-based public technology in yearly revenues. Mentor employs approximately 2750 people worldwide and reported revenues of nearly $600 million over the last 12 months.

First E-BookStore For Tech Professionals Is Launched

EAGLE ROCK, VA—When engineering, computing, and other technology professionals need a book, they usually need it immediately—even overnight delivery of a printed book is too much delay when a project deadline is approaching. Technology professionals also need books designed for quick reference and easy retrieval of desired information.

In an attempt to answer these needs, LLH Technology Publishing has announced the opening of the world's first "eBookstore" for technology professionals, eBookTech.com (www.eBookTech.com). The site features books from leading technical publishers in LLH's Deluxe eBook™ format. All titles are enhanced .PDF files and available for immediate download directly from the site and can be viewed with the industry-standard Adobe Acrobat 4.05c or Adobe eBook readers.

"Our Deluxe eBooks offer significant advantages over print books," says Jack Lewis, LLH's vice president for technology and developer of the Deluxe eBook format. "For example, the full-text search and retrieval function allows you to quickly locate all pages where a word or phrase is found. The index and tables of contents are hyperlinked to corresponding pages in the book. And each subheading is bookmarked to make 'navigating' through the book quick and easy."

"Technical books are seldom read cover to cover in the way novels are. Instead, technical professionals use books as references for needed information."

Lewis feels that e-books will be more widely adopted by technical professionals than the general public. "Technical books are seldom read cover to cover in the way novels are," says Lewis. "Instead, technical professionals use books as references for needed information. That's what makes the search-and-retrieval capability of our Deluxe eBook format such a powerful tool." Lewis adds that use of electronic documents is already widespread among technology professionals. "Most electronics, computing, and technology companies have made their documentation and other literature available in electronic form," he notes. "Our target readership is already comfortable using electronic versions of printed documents."

ETSI Publishes Mobile-Satellite Radio-Interference Specifications

SOPHIA ANTIPOLIS, FRANCE—The first-ever release of ETSI specifications for personal communications systems based on geostationary satellites was jointly developed with the US Telecommunications Industry Association (TIA) and is largely evolved from the popular Global System for Mobile Communications (GSM) standard (which was also developed by ETSI). Publication of parallel GEO-Mobile Radio interference (GMR) specifications by TIA is expected to follow later this year.

The GMR specifications include many new features, such as direct terminal-to-terminal calls that adapt and enhance the GSM radio-interface technology to make it operate efficiently over geostationary satellites. The first release of specifications includes a full set of circuit-mode services for voice and fax, as well as a range of data services. All of these services are compatible with the services provided by current terrestrial GSM systems.

US Passive Electronic-Component Demand To Top $21 Billion In 2005

CLEVELAND, OH—US demand for passive electronic components is forecast to advance nearly 4 percent per year to $21.4 billion in 2005. Above-average advances in certain end-use applications, particularly wireless and fiber-optic communications, combined with an improved outlook for the defense and aerospace sector, will support increases. Rising electronics content in motor vehicles will continue to benefit the passive-components industry. Growth through 2005 represents a significant slowdown from increases over the past decade, reflecting reduced growth in demand for passives-containing original equipment, particularly electronic equipment. Continuing competition from integrated passive devices combined with dramatic price decreases for capacitors will also limit gains to some degree. These trends are discussed in "Passive Components," a study from The Freedonia Group, Inc., a Cleveland-based industrial market-research firm.

"Connectors represent the largest segment of the passive-components industry, accounting for more than 35 percent of the total in 2000."

Connectors represent the largest segment of the passive-components industry, accounting for more than 35 percent of the total in 2000. Despite below-average increases due to the presence of a number of mature products, connectors will remain the largest segment of the industry for the foreseeable future. Microwave components and inductance devices have the best prospects through 2005. Both of these product segments will benefit from continued strength in the cellular and wireless communications market and an improved outlook for defense spending. The large capacitor market will also see above-average growth, despite expected price decreases.

Shipments of passive components are expected to rise nearly 4 percent annually to $19.5 billion in 2005. Although US passive-components manufacturers face an increasingly competitive international market environment, capacity increases in the late 1990s have allowed US producers to remain price competitive in the world market. The US is a large net exporter of parts used to manufacture several types of passive devices, particularly capacitors and inductance devices.

Most of the major passive components markets will experience cyclical slowing at the original equipment level.

Kudos

Merrimac Industries, Inc. announced that it has been granted a patent from the US Patent & Trademark Office entitled "Microwave Mixer With Baluns Having Rectangular Coaxial Transmission Lines." The patent relates to an improved multilayer mixer that enables Merrimac to offer performance benefits over other currently available mixers for microwave integrated circuits (MICs) and monolithic MICs (MMICs) at reduced size, weight, and cost...Lucent Technologies' China operations has awarded its Silver Supplier Award for Overall Performance to Pulse's Asia Business Group. Pulse, a global supplier of magnetic components, was presented with the award at Lucent's Supplier Day conference in Shanghai, the People's Republic of China. Pulse received an "A" rating for its services and is the first magnetics component company in China to achieve Silver Status at Lucent...Cardinal Components was awarded the Product of the Year 2000 Award by *Electronic Products Magazine.* The award was presented for Cardinal's new oscillator known as FIPO, the Field Instantly Programmable Oscillator. Cardinal Components is the only company from New Jersey to win the award...Signal Soft Corp. has been awarded a location-based services patent by the US Patent and Trademark Office. The patent, No. 6,212,392 B1, describes various methods for using a quadtree data structure to determine whether a wireless communications device is within a specified area, such as a service zone of a location-based services application...The three inventors of the microprocessor were honored recently by the American Computer Museum in Bozeman, MT. This year marks the 30th anniversary of the invention of the microprocessor by Dr. Ted Hoff, Dr. Federico Faggin, and Mr. Stan Mazor at the then small and little-known company, Intel...The SETI League, Inc., an organization involved in the privatized search for extraterrestrial intelligence, has awarded its highest honor to one of Europe's foremost Amateur radio astronomers. Engineer Peter Wright of Germany recently received the Giordano Bruno Memorial Award for his efforts to promote amateur radio astronomy and SETI throughout the European continent...Keithley Instruments, Inc., a company in the test-and-measurement industry, has received a 2001 NorTech (Northeast Ohio Technology Coalition) Innovation Award for its L-I-V Test System. MRF

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The broadband units also offer exceptional IP3 performance and superior linearity for the power consumed.

Part Number	Bandwidth (GHz)	Gain @ 1 GHz (dB)	Gain @ 2 GHz (dB)	P1dB (dBm)	OIP3 (dBm)	Noise Figure (dB)	Vd (V)	Id (mA)
Low Voltage Gain Blocks								
SGA-0163	DC-4.5	13	12	-2	+9	4.7	2.1	8
SGA-0363	DC-5.0	20	17	+2	+14	3.0	2.5	11
High Reverse Isolation Gain Blocks								
SGA-1163	DC-6.0	12	11	-3	+8	3.1	4.6	12
SGA-1263	DC-4.0	16	15	-8	+3	2.7	2.8	8
General Purpose Gain Blocks								
SGA-2163	DC-5.0	10	10	+7	+21	4.2	2.2	20
SGA-2263	DC-3.5	15	14	+8	+20	3.2	2.2	20
SGA-2363	DC-2.8	17	16	+8	+19	2.9	2.7	20
SGA-2463	DC-2.0	20	17	+9	+20	2.7	2.7	20

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LMDS Backers Seek Low-Cost Solutions

Reducing the cost of millimeter-wave hardware remains the greatest impediment to the LMDS quest for delivering high-speed, broadband services to the consumer.

Broadband use of the 28-GHz band has appealed to network operators for some time, although the cost of millimeter-wave hardware has remained a seemingly insurmountable barrier. While the cost of the digital and analog electronics required in a local-multichannel-distribution-system (LMDS) solution has decreased significantly, the cost of millimeter-wave components has not. This has turned LMDS system builders and service providers once keen on serving millions of residential subscribers toward creating high-speed wireless "T1 replacement" solutions for the small-and-medium-enterprise (SME) business market. Nevertheless, the lure of a last-mile millimeter-wave solution for delivering LMDS to residential markets keeps development efforts active.

It is not difficult to see why. The services that can be offered by an LMDS licensee are all-inclusive, thanks to the unprecedented amount of available spectrum. In 1998, when the Federal Communications Commission (FCC) auctioned the spectrum between 28 and 31 GHz for LMDS, each "A-

Continued on page 34

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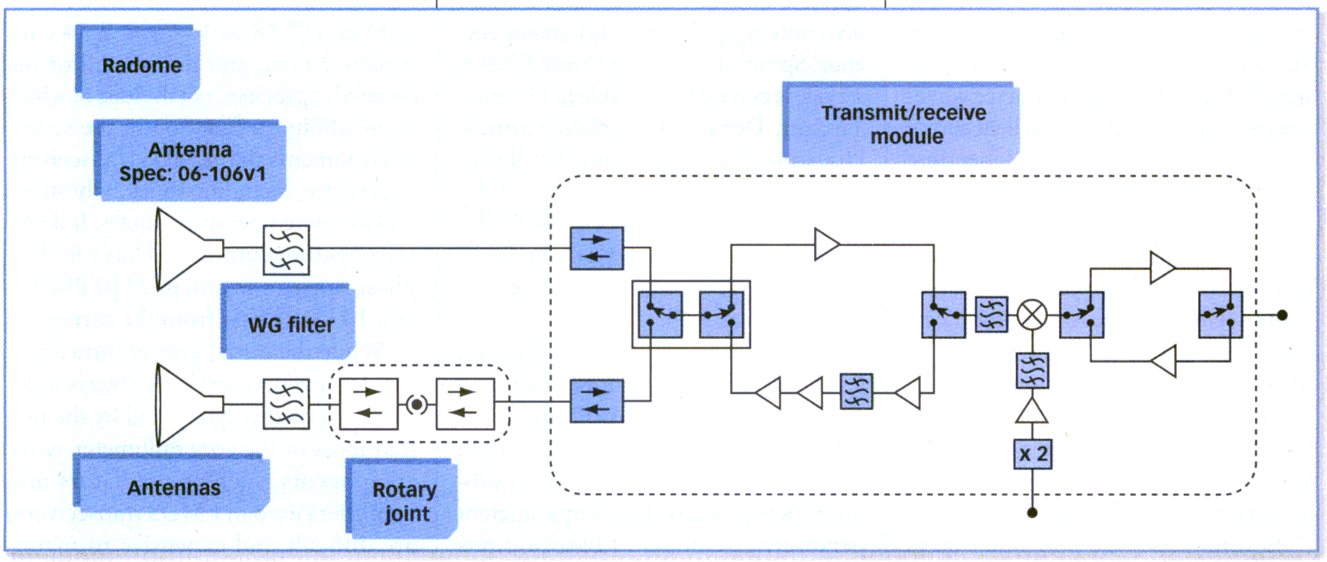

Fig 1. The Radiant Networks millimeter-wave module is designed to reduce cost while delivering high reliability and performance.

Continued from page 33

block" licensee per geographic area received 1150 MHz of spectrum. This is equal to twice the total bandwidth of the amplitude-modulation (AM) and frequency-modulation (FM) broadcast bands, very-high-frequency (VHF) and ultra-high-frequency (UHF) television, and cellular-telephone bands combined. It is also more spectrum than the FCC auctioned off in the 16 auctions prior to the LMDS auction. This huge bandwidth allows an LMDS licensee to potentially offer a breadth of services over a single path that no competitor can currently provide. Services including Voice-over-IP (VoIP) telephony to very-high-speed data and video on demand (which alone requires up to 6 Mb/s) could all be offered by a single company through one LMDS network.

The hurdles on the path to this pot of gold surround the peculiarities of propagation at 28 GHz and the high cost of millimeter-wave components. According to LMDS system manufacturers and service providers contacted by *Microwaves & RF,* the propagation difficulties can be overcome either by network topology, advanced signal processing algorithms, or both.

The issue of hardware cost refuses to go away. The history of millimeter-wave technology and its applications is mostly about aerospace and defense, since these are the applications that have employed millimeter-wave systems for satellite communications, missile guidance, and radar. The characteristics of signal propagation at millimeter wavelengths make it either an excellent choice or an extremely poor one depending on the needs of the application. For example, propagation at some millimeter-wave frequencies is hampered by massive attenuation, which makes it an excellent choice for communicating over short distances with diminished chances of interception. The high resolution obtainable at propagation "windows" in the millimeter-wave spectrum provides significant benefits for longer-range applications.

Beyond these, the only other users of millimeter-wave spectrum have been police-radar systems, motion-sensing devices, and a few industrial systems. Of all these applications, only police radar and motion-sensing applications could be considered low cost. Without the carrot of a huge revenue stream to drive its development, the millimeter-wave spectrum has remained the domain of expensive military systems.

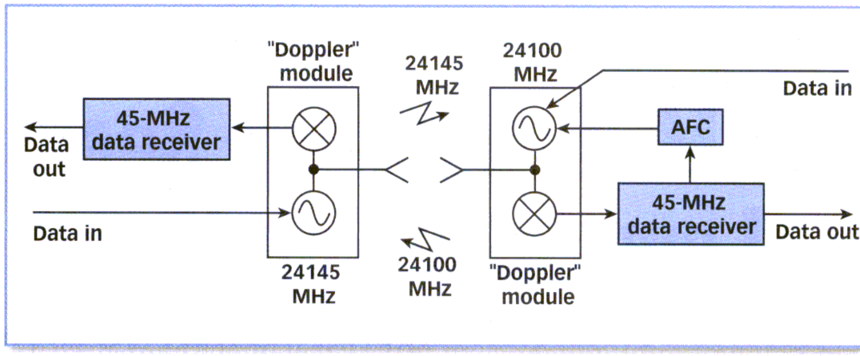

Fig 2 The low-cost LMDS concept proposed by Sweeney uses simple, Gunn diode-based transceivers.

LMDS is the first application that might change this. Analysts have forecast that the global broadband-wireless-access (BWA) market (also known as fixed wireless) could deliver more than $5 billion by 2003 and between $12 and $25 billion. However, also within the BWA umbrella are revenues from the multichannel multipoint-distribution service (MMDS) that operates principally at frequencies between 2 and 3 GHz. MMDS is far ahead of LMDS in deployment, and several carriers including Sprint and AT&T already have MMDS networks in place and are generating revenue. Sprint's Broadband Direct MMDS service is currently available in Phoenix, Tucson, Denver, Colorado Springs, Houston, Detroit, Fresno, San Francisco, San Jose, Salt Lake City, Oklahoma City, Melbourne (FL), and Wichita. AT&T rolled out LMDS service in Ft. Worth, TX, and is expanding into other cities as well.

MMDS solutions are available from a large number of vendors, including Nokia, which offers its Airheads service based on the mesh concept. The mesh approach essentially makes every subscriber a base station (or from a different perspective, eliminates base stations entirely). In general, the cost of the microwave portion of the MMDS solution is much less than its millimeter-wave LMDS counterparts. The actual contribution of LMDS systems to the lofty revenue projections remains to be seen, since it currently produces little or no revenue anywhere.

After surveying manufacturers of components, subsystems, and LMDS systems, one fact becomes starkly clear: the first manufacturer to develop a truly inexpensive LMDS solution that brings the cost of customer-premise equipment down to $300 or less may well be responsible for giving the service the last push it needs to be launched into the market.

A good example of an LMDS transceiver designed for the cost considerations of the SME market is available from L3 Communications, Narda Microwave (Hauppauge, NY). The subsystem measures 7.00 × 7.00 × 1.00 in. (17.78 × 17.78 × 2.54 cm), weighs 20 oz., and delivers all of the required capabilities, not the least of which is the ability to function in the severe environments that LMDS transceivers experience, including shock, vibration, and broad temperature ranges. It delivers +24-dBm output, and has very low phase noise of less than 2110 dBc/Hz at a 10 kHz offset from the carrier.

While the initial cost of infrastructure for any new service is always high, LMDS is further hampered by the fact that most of the core millimeter-wave components, such as oscillators and amplifiers used in LMDS transceivers, are difficult and expensive to manu-

Continued on page 36

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facture. For example, a phase-locked dielectric resonator oscillator (DRO) typically costs more than the entire projected cost of the Outdoor Unit (ODU) or customer-premise-node equipment in a residential LMDS system.

The incentive to make the commitments required to seriously pursue residential LMDS has recently been dampened by the acceptance of asymmetric digital subscriber line (ADSL) and cable modems for delivering broadband Internet access. The solutions offer a giant step up from the double-digit speeds of dial-up access at a cost of less than $50 per month. Service providers offer potential subscribers significant discounts from the cost of the required high-speed modems, or sometimes provide them with a promise of a service commitment. Competing in this paradigm is impossible for LMDS today and may well be impossible for years to come, as competition between cable and ADSL providers intensifies and fees decrease further.

However, the potential benefits of LMDS tend to retain optimism in the concept, as do the shortcomings of cable and DSL deployments. For example, rollout of DSL has been almost universally chaotic, with upstart providers attempting to compete with incumbent local-exchange carriers (ILECs) that own the infrastructure. In this market, the resellers (and their residential customers) are at the mercy of the ILECs, and several layers of coordination are required to implement each new subscriber installation.

In addition, ADSL delivers its maximum speed only a few thousand feet from the nearest telecommunications switch, with significant reduction of data rates beyond this point, to approximately 3.4 miles, beyond which it simply does not function. Forty to 50 percent of the local lines in the National Exchange Carrier Association pools exceed 3 miles, which leaves millions of people in the US unable to avail themselves of DSL, or with DSL that delivers substantially reduced performance. However, this situation is being remedied by solutions from several companies that extend ADSL's effective reach.

Finally, the version of DSL that is offered to residential customers is ADSL, which provides high-speed data transfer in one direction only—always to, but not from, the customer. Broadband cable service eliminates the problems of ADSL in coordinating installation activities, and potentially provides even higher speeds at lower delivered cost. However, this potential speed drops precipitously as more cable customers opt for broadband service. In addition, the cost of implementing and maintaining the hybrid fiber/coax infrastructure is high.

There are basically two ways to construct an LMDS network: point to multipoint and point to point, with some variations in between. In the point-to-multipoint scenario, a single base station serves a large number of subscribers with each subscriber communicating back to the base station in point-to-point fashion. This is the original LMDS architecture and the one mostly commonly employed.

The point-to-point architecture has been proposed as an alternative and is exemplified by the mesh approach taken by Nokia for MMDS, and by Radiant Networks (Essex, England). The mesh architecture significantly reduces the difficulties caused by the need for a line-of-sight communications path at millimeter wavelengths. In a point-to-multipoint network, each subscriber unit must have an unobstructed view of the base station. The larger the number of subscribers served by a particular base station is, the more difficult this is to achieve. To remedy the problem, the service provider must reduce the geographic area (cell) served by the base stations, and provide overlapping coverage of the subscriber by adding base stations.

Continued on page 38

Continued from page 36

This increases the cost per subscriber and reduces the spectrum available for each subscriber, because it must be shared between the overlapping base stations.

The Radiant Networks solution instead creates a "mesh" where subscribers connect to each other, rather than to a base station. This eliminates the need for base stations, since all subscriber nodes communicate with each other. Integrated switches at every node coupled with adaptive signal processing allow the most appropriate path to be established between nodes and the trunk network via paths through other nodes. The mesh establishes the signal-distribution pattern that offers the least amount of interference, and can be remotely reconfigured to accept additional subscribers or changes, such as the appearance of new signal-path obstacles. The peak data rate is 25 Mb/s.

Perhaps as interesting as the concept itself are the ways that the company has employed to reduce cost. Each subscriber node is comprised of two modules: the millimeter-wave subsystem and the electronics unit. "The millimeter-wave module contains little hardware and costs the most money," says Esen Bayer of Radiant. "The electronics module has lots of hardware and costs very little." The millimeter-wave module contains four antennas, waveguide filters, a transmit/receive (T/R) module, a waveguide rotary joint, and a radome.

Bayer says that while a rotary joint may seem archaic in the day of electronically steered antennas, he points out that "it's just the cheapest way to do it. Our antennas cost about $5.00 each and the motor is only a few dollars." The motors are the same as those that are used to wind electric windows in automobiles. The antenna design is based on a classical twist reflector and consists of a linearly-polarized feed horn that illuminates a polarization-sensitive subreflector.

The millimeter-wave module **(Fig. 1)** uses the dimensions of time, frequency, and spatial diversity to ensure a reliable path. Use of two different carrier

Continued on page 119


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Taiyo Yuden (USA), Inc., 1770 La Costa Meadows Dr., San Marcos, CA 92069; (800) 439-6835, FAX: (760) 471-4021, Internet: www.t-yuden.com.

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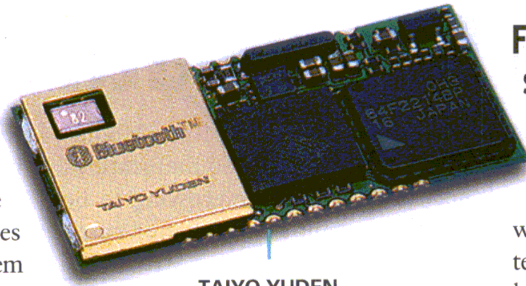

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Tektronix Measurement Group, P.O. Box 3960, Portland, OR 97208-3960; (800) 426-2200, FAX: (503) 222-1542, Internet: www.tektronix.com

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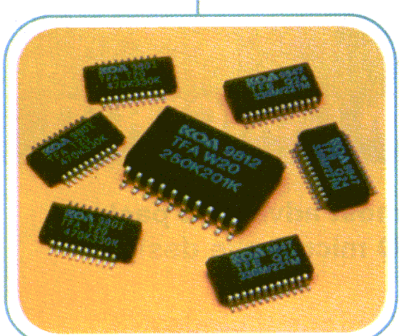

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Z-Communications, Inc., 9939 Via Pasar, San Diego, CA 92126; (858) 621-2700, FAX: (858) 621-2722, Internet: www.zcomm.com

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Z-COMMUNICATIONS PLL

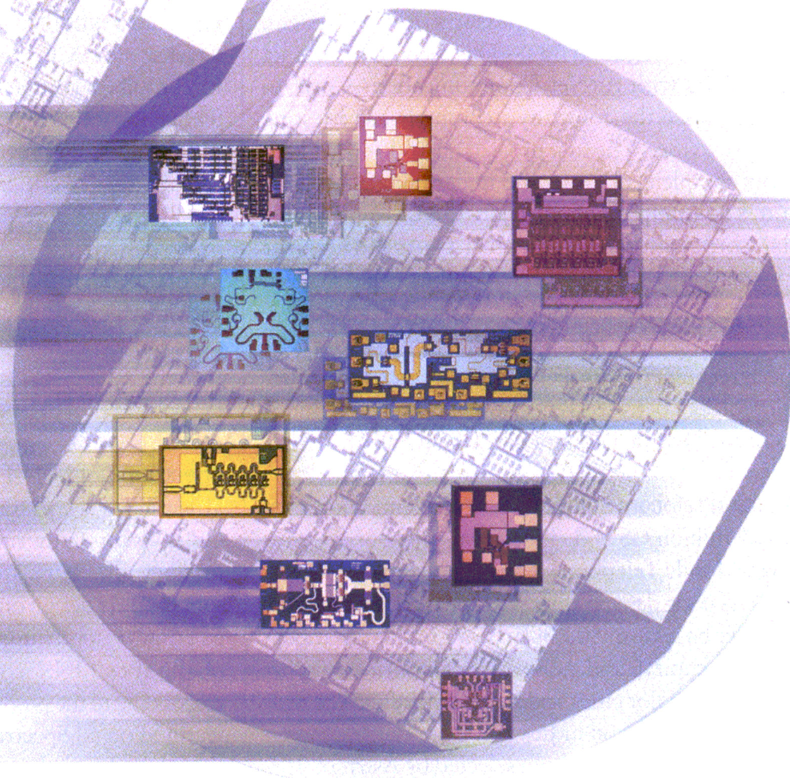
Bucks Top Bandwidth In Optics

TOUGH ECONOMIC TIMES tend to make people more practical and conservative when it comes to spending for almost anything, no matter how important or desirable. This principle holds true for fiber-optic-communications networks, which are growing to be more important as information carriers due to the tremendous growth of Internet traffic. As critical as advanced technology is to upgrading these networks, one market-research firm is advising manufacturers of DWDM subsystems and optical components to rethink their sales strategies to reflect the cost-saving features of their products, rather than trying to boost bandwidth through technological advances.

The culprit, of course, is the slowing economy, according to a report entitled "DWDM Subsystems and Components: Markets and Trends," published by Communications Industry Researchers (Charlottesvile, VA). In more bullish times, the report says, DWDM components and subsystems could be marketed to equipment vendors on the promise of extra bandwidth, which leads manufacturers to focus on exotic technologies that could push data rates on fiber closer to their theoretical limits of 40 Gb/s and beyond. Another economic drag on DWDM is its intended use in metropolitan and access markets, which are cost sensitive in good times and bad.

As fiber optics hits harder times, the five-fold growth once forecast by some analysts for DWDM subsystems will be harder to come by. Instead, the report claims that growth will be more modest, going from $855 million this year to $3.67 billion in 2005.

Cost-savings could result from a couple of new technologies that may lead the way to an all-optical network. One of these is the tunable laser which has economic and technical advantages over today's single wavelength types. Economically, the device can cut inventory costs at a large network-operations center since only a few tunable types could replace the hundreds of single-wavelength boards needed to run and maintain the system. Photonic integration is another technology that may one day lead to optical wonders, but the report stresses that the immediate focus of component makers should be on short-term cost savings rather than long-term potential. MRF



CONTRACTS

Sonofon—Has selected Alcatel for the deployment of a nationwide broadband wireless network in Denmark. In a multiyear contract, Sonofon has also selected Alcatel as its exclusive LMDS supplier for its 26-GHz spectrum license.
BAE SYSTEMS—Was awarded a $59 million contract from the US Navy for Low Rate Initial Production (LRIP) of the Integrated Defensive Electronic Countermeasures (RFCM) system.
Radio Frequency Investigation (RFI)—Has secured a contract valued at $250,000 with AirNet Communications Corp. to continue and advance the company's comprehensive testing and regulatory activities. The first project, an 1800-MHz base station, is now complete, on time, and under budget.
Raytheon Co.'s RF Components Division (RRFC)—Will supply the Hyundai Corp. with the RMPA 1951 GaAs HBT PA for the handset manufacturer's Tx-20B PCS platform. Hyundai, which is one of the largest wireless telephone manufacturers in Korea, has earmarked the dualband, trimode Tx-20B for the US CDMA market. The agreement marks the first in a series of anticipated production orders between Raytheon and Hyundai and is expected to boost Hyundai's share of the growing WCDMA market.
Motorola's Global Telecom Solutions Sector—Announced the award of a $29 million GSM digital wireless network expansion by Jordan Mobile Telephone Services (Fastlink). The network expansion is being designed to serve as phase one for increasing the subscriber base from 500,000 to 750,000, primarily in Amman, Jordan's capital, and Aqaba, Jordan's principal port city, as well as other major cities and roads in Jordan. The project is targeted for completion in July.
Merrimac Industries, Inc.—Has been selected by Astrium (formerly Matra Marconi Space) to provide a critical low-frequency, highly integrated, redundant distribution network for system clocks in the DSPs on board the three Inmarsat I-4 satellites being built by Astrium. The company projects this and future orders to be more than $1 million in 2001.

FRESH STARTS

Endwave Corp.—Has acquired M/A Com's Broadband Wireless Business Unit (BBU), initiating a strategic relationship with Tyco Electronics and making Endwave the most complete RF subsystem supplier for millimeter-wave radio OEMs such as Nokia.
ANADIGICS, Inc.—Acquired Telecom Devices Corp. (Camarillo, CA), a firm involved in the manufacture of indium-phosphide-based photodiodes for the telecommunication and data-communication markets. The acquisition of Telecom Devices will aid ANADIGICS' fiber strategy to provide high-performance, chip-set solutions by adding long-wavelength PIN photodiodes and unique packaging capabilities to its fiber product line. This transaction will be accounted for as a purchase and is valued at $28 million, plus certain earn-out payments, for a potential total consideration of up to $45 million.
Richardson Electronics Ltd.—Announced the acquisition of Aviv Electronics of Israel, providing Richardson with access to the world's second-largest market for RF and wireless start-ups. Aviv Electronics is a distributor specializing in design-in services for active and passive electronic components.
GE Electromaterials—Introduced www.GETEKconnect.com, a website for PCB design in a day. This online design center features tools for complex PCB development. Developed using Six Sigma methodology, the website integrates the life-cycle design process and a platform for supply-line management. It contains signal-integrity-critical application tools and material models used for validation of interconnect performance for each step in the design life-cycle process.
Colorado MicroDisplay—Has been selected by Carl Zeiss to provide microdisplays for use in Zeiss' OPMI® Neuro MuliiVision. The MultiVision microscope is a new method for performing microsurgical procedures, as it merges the many different sources of diagnostic information used in today's operating rooms.
Spectrum Control—Has updated its website to include several new interactive features intended to streamline search and design tasks. Visitors to the site now have access to instant product information, parametric and integrated search capabilities, and custom product design online. Spectrum Control's website is located at www.spectrumcontrol.com. Visitors to the site can click on the SPECLINK icon and enter the SPECLINK number corresponding to the product desired. (SPECLINK numbers are now featured on all Spectrum Control advertisements.) The user is then linked directly to information specific to the product that he or she is interested in.
Applied Wave Research—Signed a worldwide software-licensing agreement with Ericsson. The agreement with Ericsson Microwave Systems AB provides all of Ericsson and its affiliates worldwide with a prenegotiated licensing agreement for all of Applied Wave Research's products, including the popular Microwave Office. Microwave Office will be used by Ericsson for a wide variety of design disciplines, including GaAs MMIC design, Microwave Hybrid, and wireless handheld-appliance designs. The agreement covers all available Microwave Office configurations, as well as the popular translation software to import designs from other commonly used high-frequency design systems.
Flash Networks, Inc.—Has signed a partnership agreement with Janko Electronic Co. Ltd., a systems integrator and total solution provider located in Beijing, China. Under the terms of the agreement, Flash Networks' NettGain product lines will be sold by Janko to provide their customers with optimized wireless and satellite solutions. MRF

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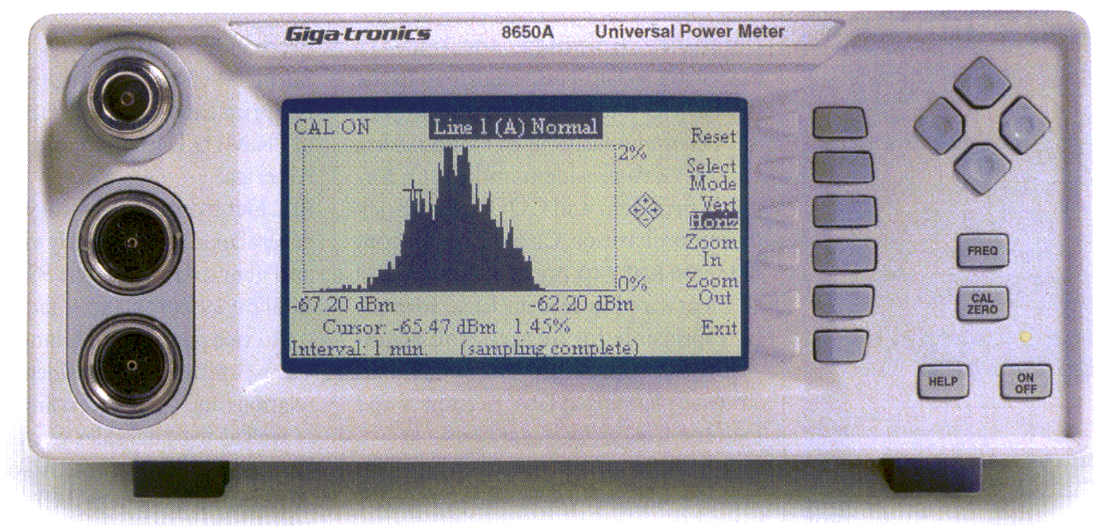

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DEMOTT

DeMott Gains Promotion At Celerity

JOHN DEMOTT has been promoted to the position of vice president of communications products at Celerity Digital Broadband Test. Mr. DeMott was previously the company's director of advanced wireless products.

Clearwire Holdings, Inc.—JIMMY MANSOUR to CEO and chairman of the board; previously co-founded National Telecommunications of Florida. Also, LEO J. CYR to president and COO; formerly president and COO at CapRock Communications Corp. In addition, BRIAN NERNEY to president and COO of Clearwire Equipment LLC; formerly responsible for mergers and acquisitions, corporate development, and strategic planning at LTV Aerospace and Defense Co.

GHz Technology, Inc.—MICHAEL YAM to vice president of engineering; formerly held management posts at Globalstar L.P. and Loral Space & Communications Ltd.

Endwave Corp.—JOHN J. MIKULSKY to chief marketing officer and senior vice president of market and business development; formerly vice president of product and business development. Also, JULIANNE M. BIAGINI to CFO and senior vice president; formerly vice president of finance and administration and corporate secretary.

Wireless Online—JULIA GILMOUR to vice president of marketing and product management; formerly headed an international management team chartered with building the US subsidiary of Martin Dawes Systems and served as vice president of business development for the newly formed business unit.

Rohde & Schwarz—WOLFGANG SCHMITT-SEIFER to managing director for marketing and sales in North America; formerly managing director for Rohde & Schwarz in Australia.

Artesyn Communication Products, LLC—JEFF DURST to director of product marketing; formerly manager of product marketing.

Sprint—YOUSEF B. JAVADI to president of Sprint International; formerly COO of PRIMUS Telecommunications North America.

RLC Electronics, Inc.—GENE LANDIS to general manager; formerly vice president and general manager at RFI Corp.

Airslide Systems, Inc.—BRUCE R. ABELDA to vice president of finance and operations; formerly vice president of investor relations and corporate communications as well as regional sales vice president at Westell Technologies. Also, MARC J. ZIONTS to president and CEO; formerly CEO of Westell Technologies.

Comtech Telecommunications Corp.—LARRY KONOPELKO to executive vice president and general manager at Comtech PST Corp.; formerly vice president and general manager of MPD Technologies, Inc.

Antenna Specialists—ROBERT TRUTHAN to director of engineering; formerly antenna engineer.

TRUTHAN

TAYLOR

AirDesk, Inc.—TIM TAYLOR to vice president of sales and marketing; formerly senior business strategist with the TM Group.

IMeet, Inc.—MANU KUMAR to CEO and chairman of the board; formerly president and CEO of SneakerLabs, Inc. MRF


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e-mail: lorraine@rttonline.com
Internet: www.rttonline.com

Low-Power Circuits and Systems for Digital Wireless Communications
June 28-29 (University of California Berkeley Extension, Berkeley, CA)
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Internet: www.unex.berkeley.edu/eng.

Electromagnetic Compatibility Engineering—EMC Design and EMI Mitigation
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Optical Layer Networking: Key Enabling Technologies and Architectures
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Internet: www.uclaextension.org/short-courses.

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MEETINGS

2001 IEEE AP-S International Symposium and USNC/URSI National Radio Science Meeting
July 8-13 (Sheraton Hotel, Boston, MA)
IEEE Antennas and Propagation Society and the International Union of Radio Science
Michael Fiddy
University of Massachusetts, Lowell
(978) 934-3306
e-mail: michael_fiddy@uml.edu

Embedded Systems Conference Chicago
July 9-11 (Navy Pier, Chicago, IL)
CMP Media, Inc.
(415) 278-5260, FAX: (415) 278-5390
e-mail: esc@cmp.com
Internet: www.embedded.com/esc

Wireless Partnerships & Alliances Congress 2001
July 10-11 (Crowne Plaza, San Francisco, CA)
International Quality & Productivity Center
150 Clove Rd.
Little Falls, NJ 07424-0401
(800) 882-8684, FAX: (973) 256-0205
e-mail: info@iqpc.com
Internet: www.iqpc.com

IEEE 2001 Conference on the History of Telecommunications
July 25-27 (St. John's, Newfoundland)
IEEE History Center, Rutgers University
39 Union St.
New Brunswick, NJ 08901-8538
e-mail: history@ieee.org
Internet: www.ieee.org/historycenter/cht2001.htm

2001 IEEE Radio and Wireless Conference (RAWCON2001)
August 19-22 (Westin Waltham—Boston Hotel, Waltham, MA)
IEEE Microwave Theory and Techniques Society (MTT-S)
Michael Heutmaker, General Chair
Lucent Technologies
Room 2-2013
P.O. Box 900
Princeton, NJ 08542-0900
(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
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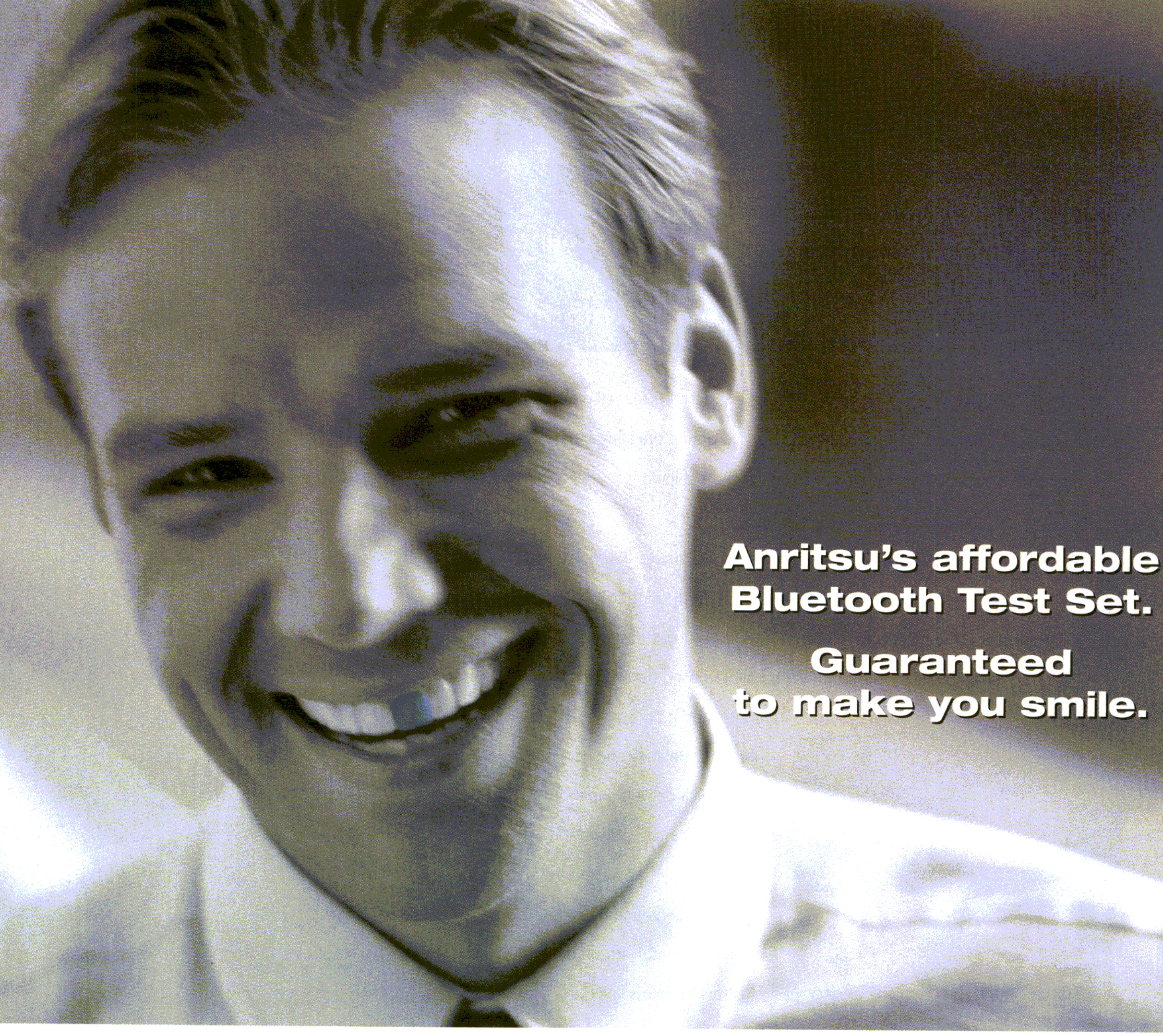

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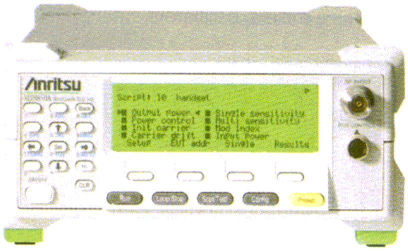

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Polarization Diversity Technique Aids Digital TV Reception

MULTIPATH INTERFERENCE AFFECTS many types of wireless communications, including digital television reception. Diversity techniques can reduce this interference. These techniques take advantage of the fact that signals from the same source that travel to the Rx over different paths can have different fading characteristics, and that deep fades rarely occur simultaneously on two or more paths. Thus, diversity techniques can dynamically select the best signal available at the Rx. The trick is to be able to differentiate—or decorrelate—signals coming from different paths. One promising method is the polarization technique, which uses two orthogonally polarized receive-antenna elements. Mercedes Sanchez and Manuel Garcia Sanchez of the Universidad de Vigo (Vigo, Spain) conducted polarization-diversity measurements using a vertically polarized transmission signal centered at 666 MHz. Gain and correlation measurement were taken in three environments: a computer laboratory where the transmission and reception antennas were within line of sight; a corridor, also with line of sight; and a corridor without line of sight. To measure the copolar component of the signal, the researchers used two vertical monopole antennas. To measure the crosspolar component, they replaced the vertical monopole antennas with two orthogonal folded dipoles. See "Analysis of Polarization Diversity at Digital TV Indoor Receivers," *IEEE Transactions on Broadcasting,* December 2000, Vol. 46, No. 4, pp. 233-239.

EM Analysis Enhances Modeling of GaAs PIN Diodes

PIN DIODES ARE used in many types of microwave circuits, including attenuators, limiters, phase shifters, and switches. The proper design of these circuits requires accurate modeling of the PIN diode's behavior. Bill Shuts of Nokia (Irving, TX), Lawrence Dunleavy of the University of South Florida (Tampa, FL), Alen Fejzuli of JDS Uniphase (Melbourne, FL), and Don Allen of Triquint Semiconductor (Dallas, TX) address two areas that they feel have not been sufficiently treated in previous modeliing efforts. The first is the accurate characterization of the electrical parasitics caused by MMIC-layout geometries. The second is an investigation of PIN-diode characteristics at low forward-bias currents. To characterize parasitics in MMIC layouts, the researchers performed method-of-moments-based EM simulations to determine equivalent-circuit models of the diode's feed structure. (The models themselves were verified using a conventional simulator.) The equivalent-circuit representations were used to de-embed the parasitic effects of the feed structures from measured extrinsic S-parameter data. They then used the resulting intrinsic data representations to determine the elements of their proposed intrinsic PIN-diode circuit model. In the low forward-current investigation, the researchers conducted measurements at several forward-bias conditions below the device's "turn-on" threshold, and found that these measurements more accurately model the device's impedance than the simple "on-state" models found in existing literature. See "Small-Signal Modeling of GaAs PIN Diodes Aided by Electromagnetic Analysis," *RF and Microwave Computer-Aided Engineering,* March 2001, Vol. 11, No. 2, pp. 61-67.

Magnetic Plate Increases Cell-Phone Efficiency

THE ABILITY OF a cell phone to efficiently transmit signals is affected to a large extent by the surrounding environment, which almost always includes a human body. Its absorption of the phone's signals is significant, and the recent trend toward smaller cell phones makes the body's attenuating effect even more pronounced. Eiji Hankui of NEC Corp. (Kanagawa, Japan) and Osamu Hashimoto of Aoyama Gakuin University (Tokyo, Japan) have conducted research on reducing this interference by controlling the magnetic field near the cell phone's antenna using a small magnetic plate between the cell phone and its user. They contend that this magnetic plate alters the cell-phone antenna's near-field distribution, but has very little influence on its far-field distribution. The researchers modeled a cell phone using a quarter-wave monopole antenna mounted on an 8.0 × 4.0 × 0.25-cm metal box . A 4.0 × 4.0 × 0.5-cm magnetic plate was placed parallel to the metal box, just below the antenna, at a distance of 0.5 cm. Their human-head model was a cylinder 20 cm in diameter and 18 cm high placed 1 cm away from the magnetic plate. See "Increasing the Radiation Efficiency of Cellular Telephones by Controlling the Nearby Electromagnetic Field Around a Human Model," *Microwave and Optical Technology Letters,* April 20, 2001, Vol. 29, No. 2, pp. 104-107.

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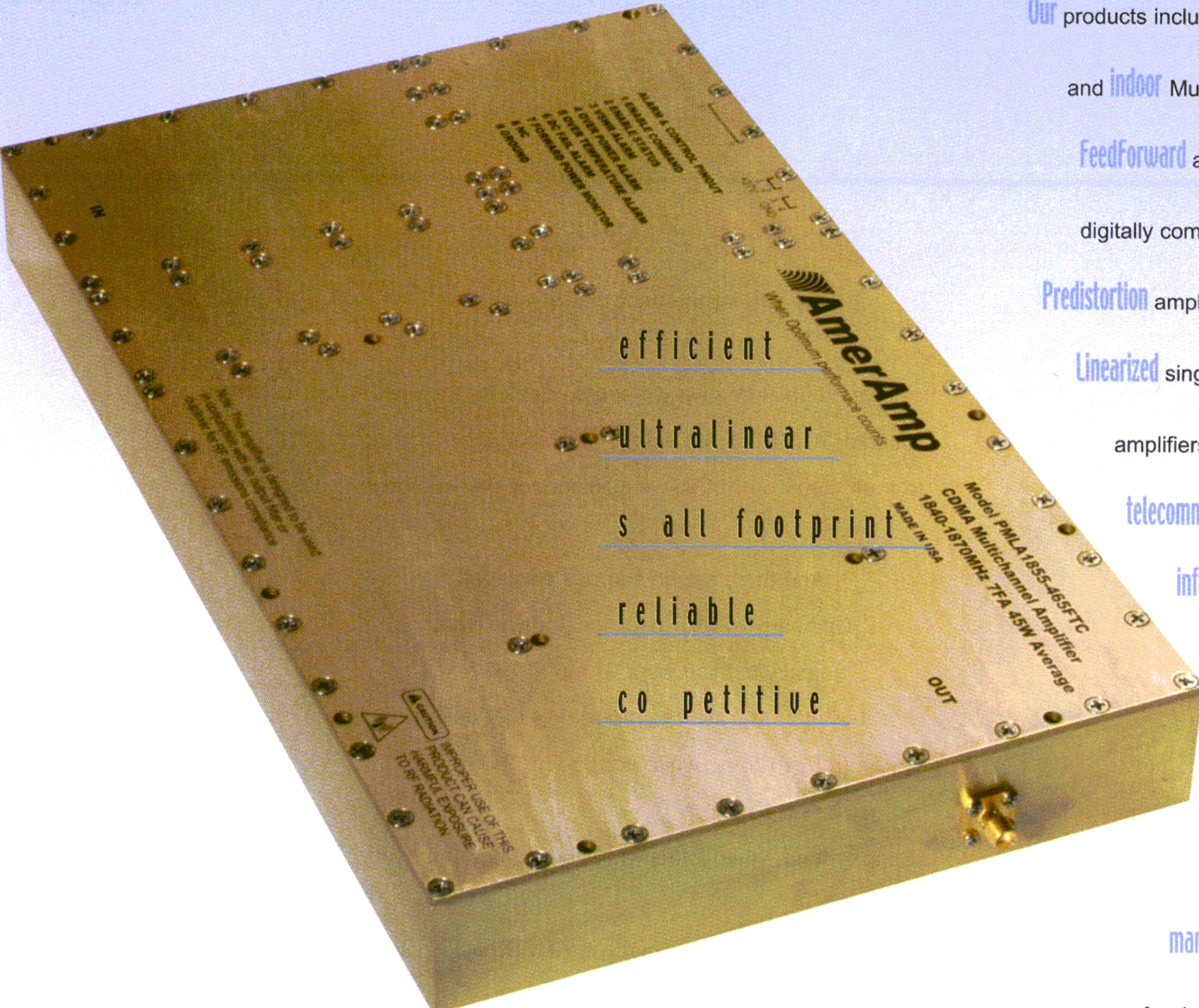

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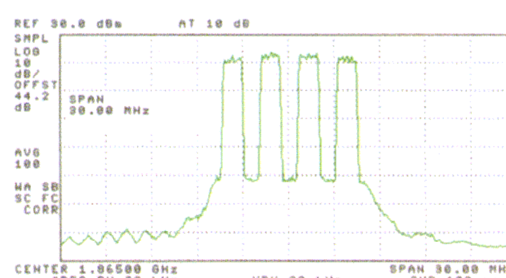

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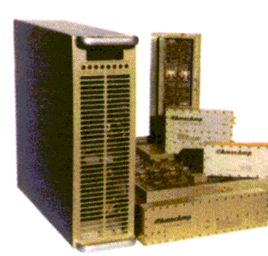

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Reviewing The Basics Of MMIC Design

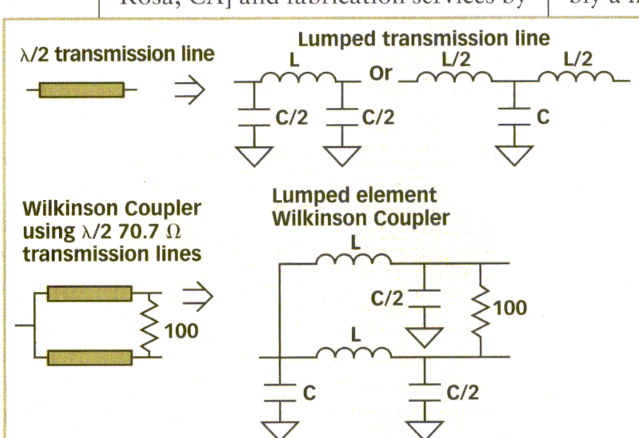
This examination of some student MMIC designs can help first-time designers understand some of the pitfalls involved in assembling practical circuits.

JOHN PENN AND CRAIG MOORE
Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD 20723 and
JHU Whiting School of Engineering, Johns Hopkins University, Baltimore, MD 21203

Monolithic microwave integrated circuits (MMICs) have been a key part of microwave-development strategies since major technology advancements were funded by Defense Advanced Research Projects Agency (DARPA) as part of the MIMIC program in the 1980s. Today, MMICs with tens or even hundreds of monolithic active and passive components can be designed with computer-aided-engineering (CAE) programs and fabricated at commercial foundries. To help engineers who are new to the experience of designing MMICs, what follows is an overview of MMIC design topics and examples of MMICs designed by graduate students in the Johns Hopkins University (Laurel, MD) MMIC Design Course. The course has been co-taught by the authors since 1989, and is well-supported with software and test hardware from Agilent Technologies (EEsof, Inc.) [Santa Rosa, CA] and fabrication services by TriQuint Semiconductor (Hillsboro, OR).

The term "MMIC" should not be confused with microwave IC (MIC). An MIC is a combination of elements on a board similar to a hybrid. The term "MIC" is somewhat of a misnomer, since miniature IC designs in the 3-to-30-GHz range are referred to as MMICs, whereas the term MIMIC (from the DARPA program) is used to designate microwave or millimeter-wave IC designs from 3 to 300 GHz. Designs operating at 2 GHz or below may sometimes be called MMICs, but the term RF IC is probably a more accurate definition. By the traditional MMIC definition, many silicon MMICs would be Si RF ICs. Gallium arsenide (GaAs) is the material of choice for MMICs with many more exotic III-V semiconductor materials being used for MIMICs or photonic devices.

How small are MMICs? A dozen or so could probably fit on a fingernail. Typical MMICs might be from 1 to 3 mm on each side and approximately 0.1 mm thick.



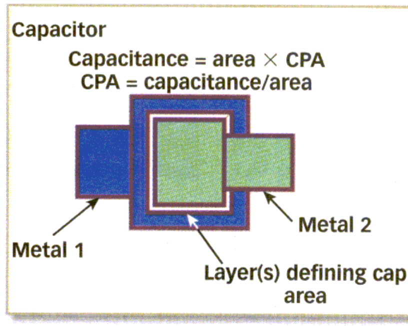
1. Distributed-circuit elements can be converted into lumped-element equivalent-circuit elements to save space on a MMIC layout.

Better understanding of MMIC device models and processing techniques leads to better designs. The following are the basic design components in MMIC and how they are used.

An assortment of transistors, capacitors, resistors, inductors, and microstrip lines are common elements in MMIC design. Whether to design with distributed elements or lumped elements is a function of the design frequency and the available GaAs wafer area. At millimeter-wave frequencies, quarter-wave elements are useful, but at lower microwave frequencies, a quarter-wave element is not likely to fit on a reasonably sized GaAs IC die. Fortunately, a lumped-element equivalent of that quarter-wave element can be used to conserve MMIC wafer area **(Fig. 1)**.

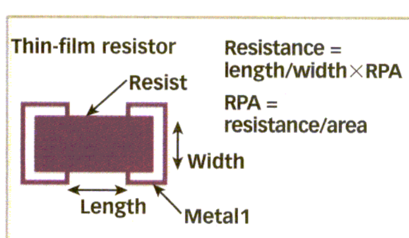
Capacitors are formed from two plates of metal with a dielectric separating the plates **(Fig. 2)**. The value of the capacitance is proportional to the area of the plates and depends on the thickness and relative dielectric constant of the separating material. Since the thickness and type of dielectric for the capacitor are usually fixed for a particular process, foundries often specify a capacitance per unit area. The designer specifies the capacitor values by defining their size (i.e., layout).

Resistors are often formed with a thin deposition of a resistive material such as nickel chromium (NiCr), or a resistive material similar to it **(Fig. 3)**. Other materials, including ion-implanted GaAs regions, can be used for resistors. Often a foundry will provide several types of resistors to cover various ranges for very small resistances or very large resistances. MMIC designers use the concept of resistance per square. The length or width of the resistor is not as important as its aspect ratio. Adding resistors in series increases total resistance. Adding resistors in parallel decreases resistance. So, MMIC resistors are proportional to length and inversely proportional to width leading to the concept of resistance per square. If resistors are designed to be wide enough to carry the DC current, then the length is calculated based on the material's Ω per square value.



2. A capacitor's value is proportional to the area of the plates and depends on the thickness and relative dielectric constant of the separating material.

Inductors are made from lengths of relatively narrow microstrip lines, depending on the design frequency and length required. Often, inductors are manufactured from spiral circular or rectangular shapes to obtain the most inductance in the least amount of area. MMIC inductors are often lossy, but increasing metal thickness or line width can reduce the resistive loss of the inductors and improve their quality factor (Q). Whether the MMIC fabrication process uses metal-semiconductor field-effect transistors (MESFETs), heterojunction bipolar transistors (HBTs), or pseudomorphic high-electron-mobility transistors (PHEMTs), one of the big advantages of MMIC design is that it is usually possible to specify exactly the device desired and to optimize the device size to the specifications and requirements of a design. Normally, a design process is optimized for either low-noise capability or power capability, but not both. TriQuint's TQTRX process, however, combines "low-noise" MESFETs with "power" MESFETs on the same wafer. MESFETs are general-purpose GaAs transistors, but the more complex PHEMT transistors may be desired for very-low noise, high efficiency, linearity, or millimeter-wave performance.



3. Resistors for a MMIC process are often formed with a thin deposition of a resistive material such as NiCr.

Quarter-wave elements are too large for a MMIC at 3 GHz, but they are reasonably sized at 37 GHz. Microstrip elements are commonly used as impedance-matching elements at high frequencies. These elements represent simple nodal connections at low frequencies. Coplanar elements can be used and are common at millimeter waves. Coplanar elements require more area and design effort than microstrip. Square microstrip corners are preferred over optimally mitered bends. When the bend is so small that it represents a hundredth of a wavelength or less, the current-carrying advantage of a square corner is preferred to the very narrow mitered bend. Modeling of relatively short narrow microstrip can often be ignored as long as it satisfies the current-carrying requirement.

Designing with MMIC design elements is similar to designing MIC circuits with some new constraints. Use a good microwave simulator CAE tool with the appropriate models to design the initial MMIC. Agilent EEsof's Series IV suite of software programs or the newer Advanced Design System (ADS) design tool has the layout of the MMIC elements tied to the design schematic. The MMIC layout tool can be separate from the simulation tool, but a combined simulation/layout tool will make major layout errors less likely. Understanding the processing steps in fabricating a MMIC and becoming familiar with a particular foundry process leads to better designs.

The initial design of a MMIC requires the same basic elements and simulator tools as an MIC design, but the MMIC layout is considerably different. Processing of the GaAs is a series of steps that generate a thin sandwich of materials that define the transistors, resistors, capacitors, and interconnects, thus forming the desired circuit. Each step in the IC process requires a definition of polygons, squares, or circles that

Continued on page 58

Continued from page 56

make up an individual mask. The combination of masks defines the size of the capacitor elements, resistors, transistor sizes, interconnecting junctions, and metal overpasses. Advanced MMIC designers will think of their circuits not just in terms of the schematic, but in terms of the actual three-dimensional (3D) interconnect of the mask-processing steps.

A good design rule check is essential to verify that the widths, spacings, and combinations of mask patterns can be physically produced with a high yield. There are advantages to having the capability to perform design-rule checks in house, but all foundries can perform design-rule checks for the designer. A MMIC library designed by Gary Wray of Agilent EEsof was used to generate MMIC designs using Agilent EEsof's ADS design tool for this past fall's Johns Hopkins MMIC Design Course. Completed student designs are then design-rule checked with the "relatively" inexpensive IC Editors, Inc. (ICED) layout tool using rules provided by TriQuint Semiconductor. Design-rule errors that affect minor mask changes, and not schematic changes, are usually corrected using ICED by the instructors. Final layouts are then submitted for fabrication.

Using a library that has software macros to generate design-rule-correct layers for each element is an easy way to minimize design-rule errors and increase productivity. Another design method is to use a simple layout tool and stretch the element layers of a known good component into a new design or value. A software macro generates design-rule-correct layers for an element based on a simple specification such as a resistor of width "x" μm with a value of "y" Ω. Good foundry libraries will have a set of macros to generate design-rule-correct elements for that particular process. Macros help eliminate errors but do not negate the need for a final design-rule check. The components may be generated as design-rule correct, but certain combinations of individually "correct" elements can create a design-rule error. Experience with the foundry library and process will help avoid those combinations of elements that create design-rule errors. When in doubt, someone at the foundry can explain design-rule problems and their solutions to the MMIC designer.

Linear models and linear simulators can meet most design needs. Foundries usually provide element models for the transistors at various bias points. A standard-size transistor is usually provided and the designer must scale it to a different size to customize the element. A typical MESFET might have six gate fingers, each with an effective width

Continued on page 60

With the demand for power amplifiers in RF wireless infrastructure, assembly has to be fast. However, throughput has to be combined with accuracy and steady state eutectic temperature control to increase yield. Palomar's fully automated, in-line, HotRail RFA (Radio Frequency Assembly) component assembly cell is the answer. HotRail handlers preheat the parts while the HotRail clamping mechanism holds them in place so that they are perfectly aligned and ready for attachment. You get ±10 micron accuracy and void-free attach. Fragile and sensitive parts, including die as thin as 3 mil, can be picked and attached from any presentation device. The system is completely integrated with high capacity input and output magazine handlers providing capability to load an entire shift of parts, eliminating operator intervention.

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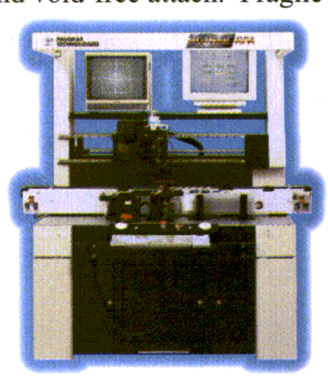

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of 50 μm to produce a total effective MESFET gate periphery, or a width of 300 μm. A smaller 150-μm MESFET can be made from a 300-μm model by scaling the six fingers to 25 μm width. Capacitance increases in proportion to the total FET width, resistance increases in inverse proportion to the total FET width, and inductance might scale in proportion to the number of gate fingers divided by the individual gate-finger width. Foundries usually provide scaling rules for modeling elements that are not at standard sizes.

Using linear models alone, one could design amplifiers, oscillators, phase shifters, etc. Linear models extracted from measured devices tend to be very accurate when they operate at a small signal and near the bias point of the model. Scaling components far from nominal may lead to errors. Operating the device with large-signal drive or in a non-linear mode will require nonlinear models and simulation capability. Even when designing low-noise amplifiers (LNAs) that require linear simulations with noise data, it is important to perform a nonlinear simulation to ensure correct biasing of the circuit.

Accurate nonlinear models and a nolinear simulator are needed to design power amplifiers (PAs), frequency multipliers, mixers, etc. Understanding non-linear model generation is quite an art. A model

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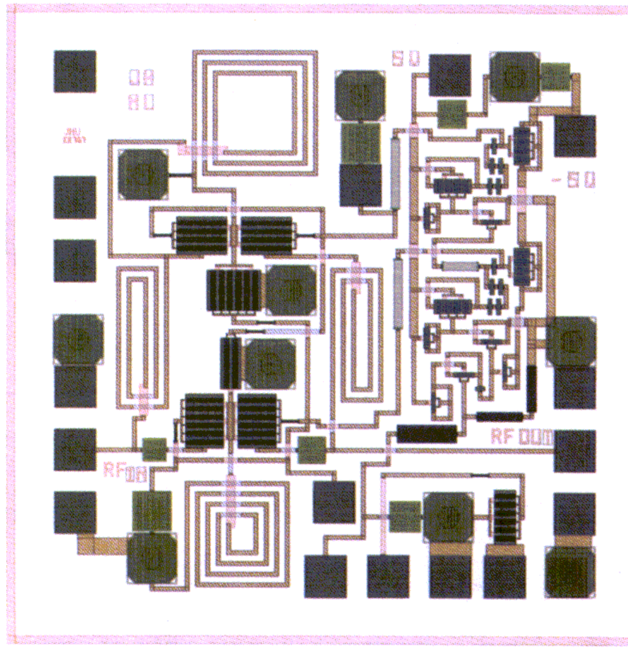
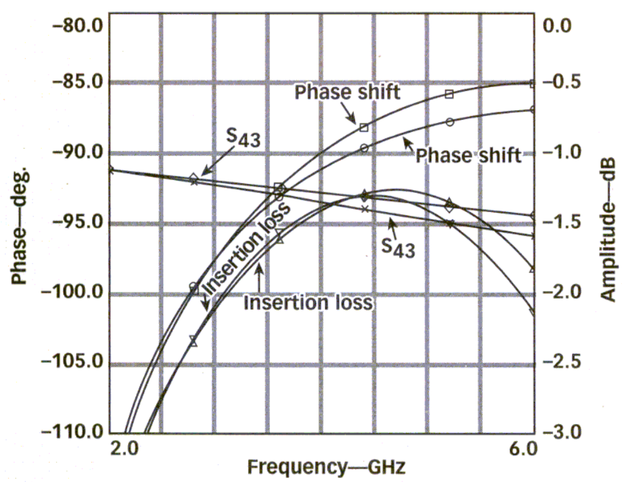
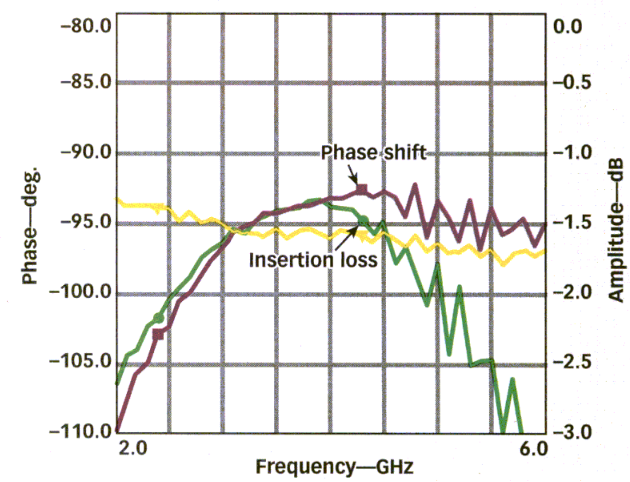


4. This IC layout shows the GaAs-MMIC quadrature modulator.





5. The simulated phase and insertion loss of the quadrature modulator (left) are compared to measured results (right).

Continued from page 60

that works well for a MESFET device may not work well for a PHEMT device. A model that is optimized for power compression may not be appropriate for designing a mixer, or for calculating third-order intercept point (IP3). It is important to know the limitations and strengths of the particular nonlinear model. TriQuint's Own Model (TOM3) for the TQTRX process is a "reasonable" model over a very wide range of bias. JHU graduate students have successfully designed a few nonlinear designs using the TOM model. However, if one were going to design a circuit using a MESFET as a varactor

Continued on page 64

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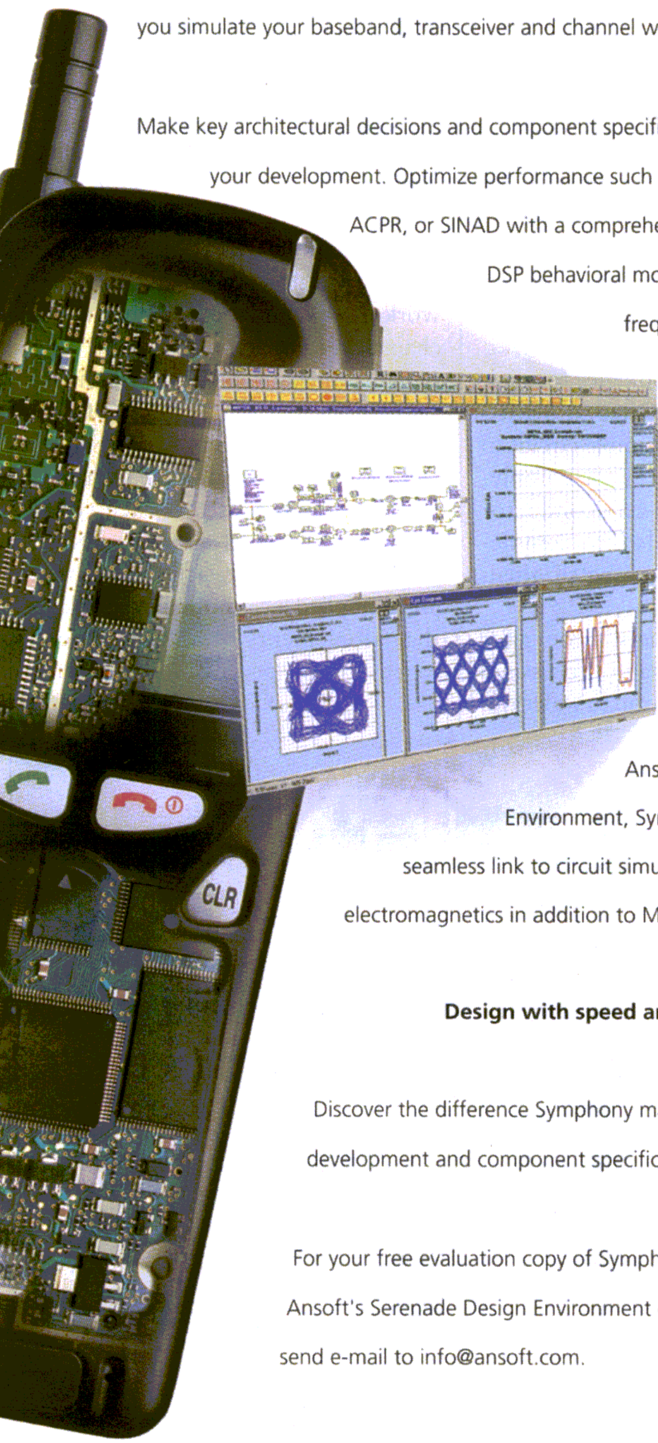

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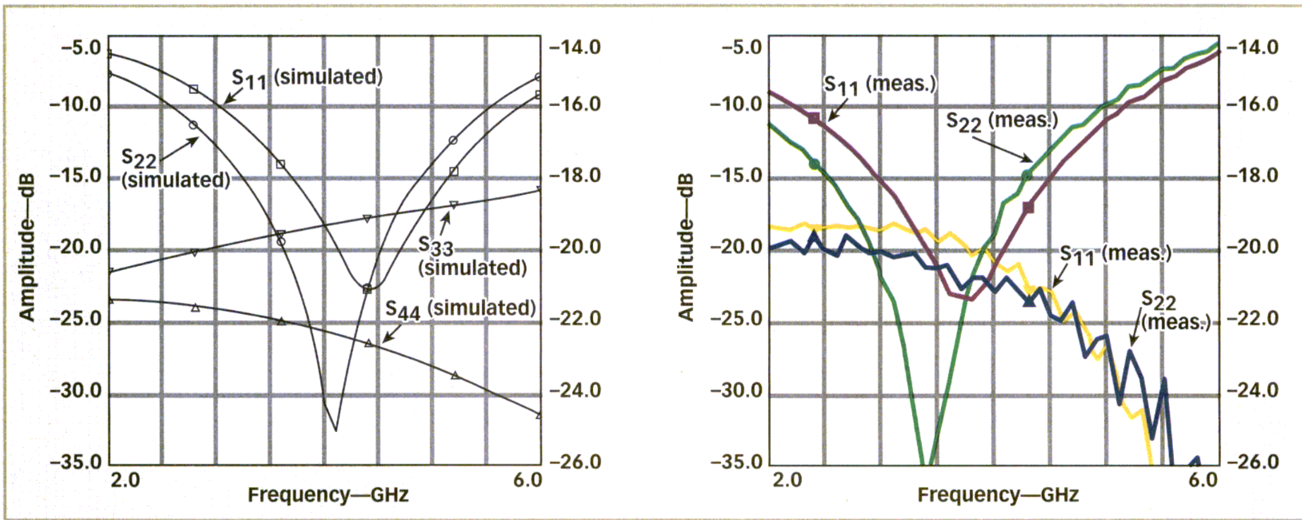

6. The simulated input and output reflection coefficients of the quadrature modulator (left) are compared to measured results (right).

Continued from page 62

diode, one would use a different set of "TOM" model parameters optimized for reverse-bias operation. The foundry and/or the simulator company can usually provide guidance for the appropriate use and limitations of the various nonlinear models.

Electromagnetic (EM) analysis is another useful tool that fills gaps in linear and nonlinear simulations.[1] Assumptions of noninterference between elements in linear and nonlinear simulations may not be valid when elements are spaced too closely together. An EM simulator may be needed when undesired interaction or coupling occurs between elements placed too closely in the MMIC layout. Whether this type of simulator is needed depends on the design frequency, the compactness of the design, and the type of design. For student designs in the JHU MMIC Design Course, few have required EM analysis. But if one is designing Ka-band or V-band circuits with PHEMTs, some EM-simulation capability will be desirable. Even at low frequencies, a MMIC design that is extremely dense and compact may require EM analysis. Transistors can be used for switching devices, attenuators, and phase shifters. Separate linear models will be needed from the foundry for switch devices. Nonlinear models generally do not accurately model the extreme bias variations of the "on" and "off" switch. A simple linear "on" model for a switch is a resistor whose value is inversely proportional to the total FET width. In the "off" state, a simple model is a capacitor whose value is proportional to the total FET size.

There are many topologies for digital circuits in GaAs. Often, a MMIC designer only needs a simple circuit to translate standard TTL or complementary-metal-oxide-semiconductor (CMOS) input signals into complementary FET biases for a switch, attenuator, or phase shifter.

Experienced designers account for design variations in wafer processing. Variations from wafer run to wafer run are much larger than within a wafer lot. Dice within a wafer should have extremely similar behavior. If resistors can vary 610 percent between wafer runs, the variance within a run is negligible. All resistors within the wafer will vary by the same amount. Ratioing techniques work very well as a resistor-divider network. Both components in the divider change the same amount while the ratio remains unchanged. Consider this in simulations and avoid a Monte-Carlo analysis with elements varying independently. Create a multiplier variable for capacitors, resistors (each type), and transistor-model parameters. Next, create equations for each element that are multiplied by a common variable so that all elements of a "type" move together with processing variations.

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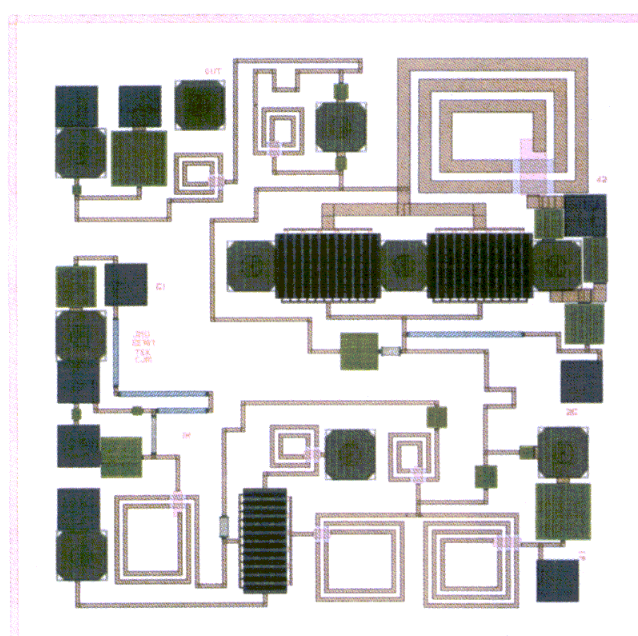
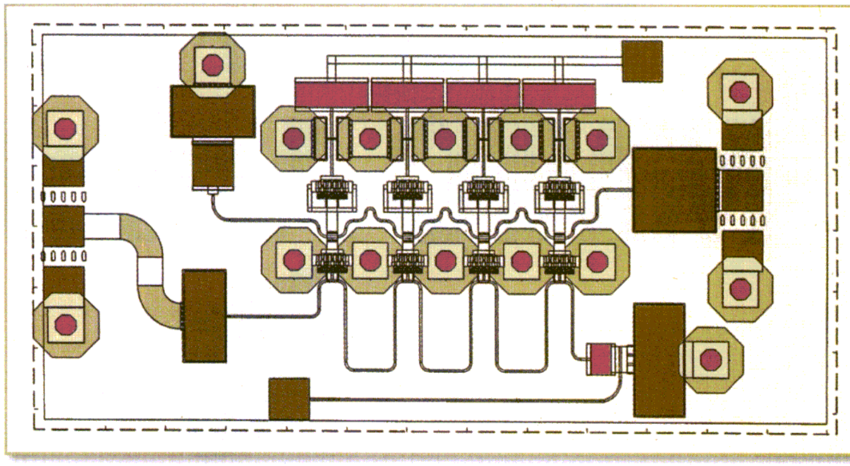


7. This IC layout shows a GaAs-MMIC PA with approximately 1-W output power from 2 to 6 GHz.

Continued from page 64

Ratioed values should stay constant.

There are a couple of simulation strategies to account for processing variations. One is Monte-Carlo analysis, where common multiplier variables will change according to a Gaussian distribution. Another method is to take the worst-case extremes of the models and then check the extremes of the processing ranges. Either method is valid. The important point is to have some idea of how sensitive a circuit design is to normal processing variations and possibly build some compensation into a design such as selectable bond pads for alternate bias points. A simple check is to vary all resistors ±10 percent, then all capacitors ±10 percent, etc., while looking for any dramatic changes in the design's response. An impedance-matching circuit that depends on a very high Q or has a "loop" near the edge of the Smith chart is a situation to examine carefully. Otherwise, simulations could deviate greatly from actual performance. On the positive side, interconnects that are in many designs (below 10 GHz) are such a small fraction of a wavelength that the original first-cut simulation without interconnect is usually very close to the simulated response. This includes all of the layout interconnect.



8. This IC layout shows a four-stage distributed amplifier designed for use from 1 to 24 GHz.

Another advanced topic is compensation for temperature effects. Temperature data may be difficult to obtain.

Continued on page 68

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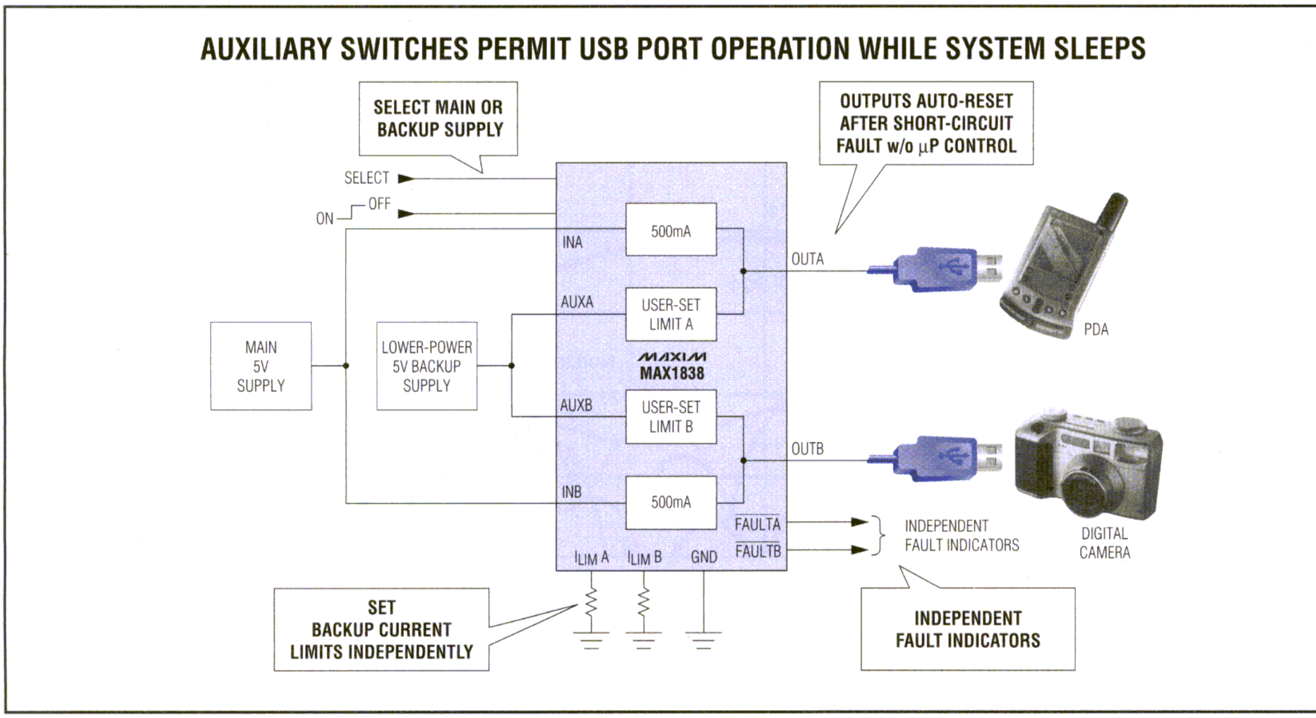

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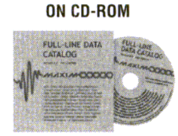

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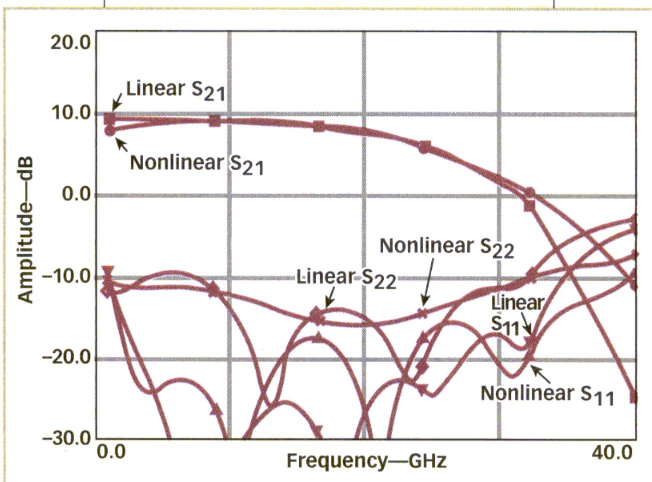
One simple trick is to use components in the biasing circuit that drift identically to the devices being controlled. Choose elements that are less sensitive to temperature drift, such as thin-film NiCr resistors over implant resistors. If possible, model the effects of temperature on the design.

TriQuint Semiconductor, for instance, offers a prototyping service where the cost of a wafer fabrication is split among several designers. For a fraction of the cost, one can prove out a design or iterate a design at a low cost before committing to an expensive production run. Typically, these services are offered two to four times a year depending on the process desired and are limited to a few common die sizes. TriQuint's Prototype Chip Option (PCO) has prices and schedules listed on their website at www.triquint.com.

Another more-expensive prototyping method is to buy a small wafer run. TriQuint calls this service a Prototype Wafer Option (PWO). This is a common service with all foundries. A small wafer run includes the full costs of masks—often the biggest part of the expense, and the fabrication of a few wafers—usually two to five wafers. More control of the schedule and die sizes is gained with a full wafer option versus a shared wafer option. Since a lot of die will be obtained, it is good to put multiple versions of a design or several different types of designs on a single wafer run. Adding many designs and design variations to the initial prototype wafer run will improve the odds of first-pass success and reduce the cost-per-design type.

Calibration Structures

Accurate measurements of MMIC devices and chips require the right equipment and techniques. Even the foundry needs accurate measurements of the devices in order to provide models to the designers. On-chip calibration structures can be designed or substrate standards from probe manufacturers can be used. Reference 2 discusses some of the issues with on-chip calibration structures and probe measurements. Probe measurements of devices such as PAs can be difficult. Removing the heat from the device and squelching low-frequency oscillations are important. Sometimes attaching amplifier die to a piece of metal to spread the heat and wirebonding larger decoupling capacitors to the device-bias inputs may make it possible to probe an amplifier die.



9. The results of linear and nonlinear simulations are compared for the 1-to-24-GHz distributed amplifier.

In the Johns Hopkins University MMIC Design Course, students have designed for a variety of MMICs with operation from DC to 40 GHz.[3] The vast majority have been designs in the 2-to-8-GHz range using TriQuint's process and fabrication services. Student designs include switches, phase shifters, attenuators, LNAs, distributed amplifiers, general-purpose amplifiers, PAs, mixers, voltage-controlled oscillators (VCOs), frequency doublers and triplers, active circulators, and quadrature modulators. What follows are examples of typical student MMIC projects. This should provide the reader with an idea of what can be performed by a first-time MMIC designer. Part-time graduate students completed all of these designs over a six-to-seven-week period.

A quadrature modulator designed by M. Long and J. Xiang in the Fall of 1998 illustrates a combination of MMIC design techniques. It includes a 90-deg. phase shift with a digital driver to convert a TTL/CMOS input signal into the differential-switch voltages for the phase-shift bit. To create a binary-phase-shift-keying (BPSK) or quadrature-phase-shift-keying (QPSK) system, two or three of these modulators would be cascaded. **Figure 4** shows the modulator layout on a 54 × 54-mil GaAs IC with TriQuint's TQTRX process.

Measured and simulated results for the two phase states are shown in **Figs. 5** and **6.** The left portion of each figure illustrates the original student simulations with measured results shown in the right half of the figures. There is close agreement between the simulations with a linear-switch model, simulations with the nonlinear TOM2 model, and measured results of the modulator MMIC. Power consumption for the TTL/FET drivers was 25 mA at ±5 VDC as predicted. The phase shift was measured at 93 to 96 deg. from 3 to 6 GHz with matching (return loss) of better than 10 dB from 2 to 5 GHz.

A broadband two-stage amplifier was designed by C. Martin and T. Knibbe in the Fall of 1998 for operation from 2 to 6 GHz with approximately +30-dBm output power on a tiny 54 × 54-mil GaAs IC **(Fig. 7)**. In order to test the final device, the IC was solder-attached to a piece of metal and then measured with a probe station. The thin metal plate was sufficient to spread the heat enough to obtain better than +29-dBm output power using a +7-VDC supply. The power-added efficiency (PAE) was approximately 25 percent, as expected. Measurements were performed at mid-band (4 GHz) with DC consumption of 0.45 A at +7 VDC and +29-dBm output power at approximately 1-dB compression.

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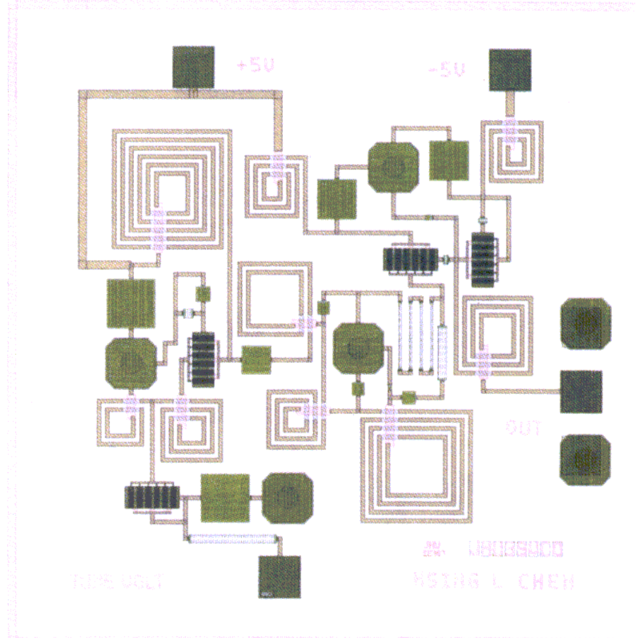
A four-stage broadband distributed amplifier was designed by J. Larner in 1997 for operation from 1 to 24 GHz. **Figure 8** shows the proposed layout of the distributed amplifier with simulated performance shown in **Fig. 9.** This design was not fabricated due to a change in ownership at the intended foundry.

VCO Layout

A VCO was designed by H. Chen in 1999 for a 5.7-to-5.9-GHz range. The actual part had +8 dBm of output power with a tuning range of approximately 250 MHz. Actual oscillation frequency was approximately 10 percent high. It was apparent during the design phase that the design was sensitive to modeling of the elements so the shift in frequency was not unexpected. Loads required to produce oscillation are often near the edge of the Smith Chart where models seem to have the largest errors. It is important to analyze the sensitivity of the design in the simulator tool. For this design, MESFET varactor diodes were used for the tuning elements of the VCO. **Figure 10** shows the VCO layout on a 54 × 54-mil GaAs IC with the TriQuint TQTRX process.



10. This IC layout shows the GaAsMMIC VCO designed for use from 5.7 to 5.9 GHz.

Many GaAs foundries including TriQuint have their own multiple day courses for MMIC design. Several Universities have MMIC Design Courses. The MMIC Design Course (EE787) at Johns Hopkins University, taught since 1989, is a one-semester course for graduate students. Another Course at JHU, taught by Dale Dawson since 1990, is the Power MMIC Design Course (EE788) which goes into detail about issues relevant to PA design. For more information on the MMIC Design Course at Johns Hopkins University courses, visit the website at www.apl.jhu.edu/courses/ee/525.787Penn.html. MRF

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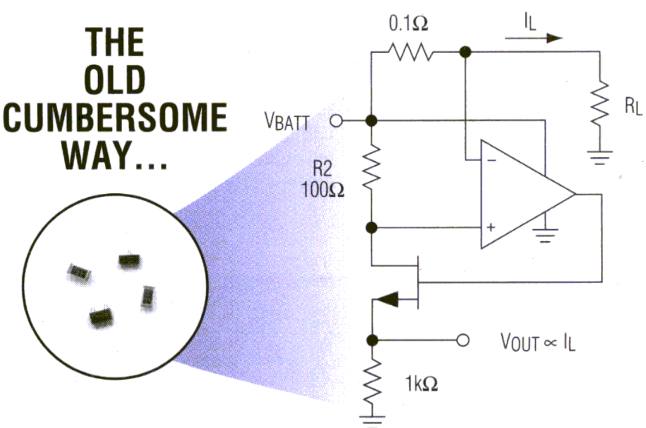

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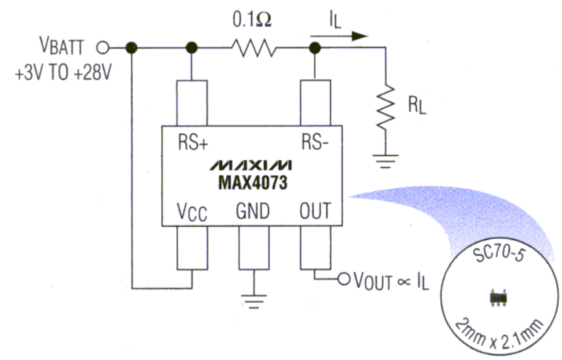

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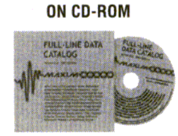

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Design A Tunable Resonant-Tank Circuit

The use of a mathematical modeling program and a versatile linear simulator can help to demonstrate the effectiveness of the design equations developed in Part 1 of this series.

Designing tunable resonant-tank circuits was shown last month in Part 1 to require an understanding of the various parasitic circuit elements that can affect performance. To demonstrate the power of the design equations developed in Part 1, example circuits will be simulated with both MathCAD software from Mathsoft Engineering and Education, Inc. (Cambridge, MA) and the LINC2 linear simulation program from Applied Computational Sciences (Escondido, CA).

SAM BELKIN
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MathCAD was used to analyze a design example where design frequencies of F_1 = 550 MHz and F_2 = 450 MHz were used, along with a low tuning voltage (V_{tl}) of +0.5 VDC, a high tuning voltage (V_{th}) of +2.5 VDC, parasitic capacitance of 3 pF, and a frequency deviation (m) of 20 MHz. The tuning range consisted of $F_{max} = F_1$ + m (570 MHz) and $F_{min} = F_2 -$ m (430 MHz). The value of K_f was calculated from F_{max}/F_{min} = 570/430 = 1.3256, with the value of K_f^2 = 1.7572.

A preliminary inductance value of 10 nH was chosen for this example, with preliminary tank capacitance, C_{tmin}, of $(2.533 \times 10^7)/(F_{max}^2 \times L)$ = 7.7962 pF which, for convenience, is rounded off to a value of 8 pF. The required tuning capacitance range, ΔC_r,

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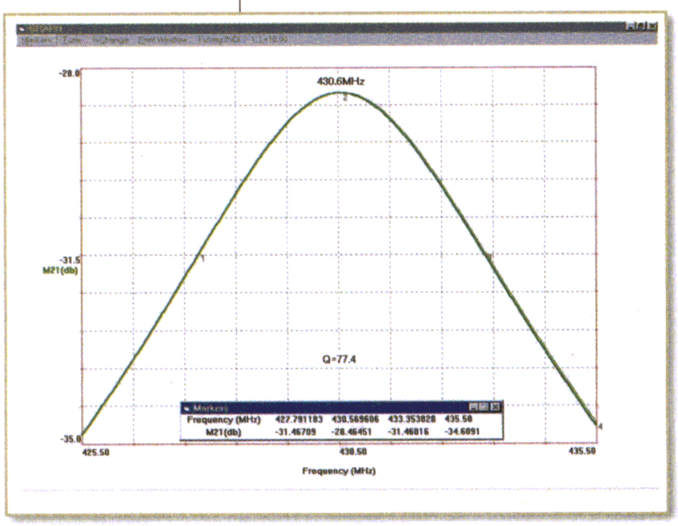


Fig. 8 This plot shows that lower frequency F_{min} = 430.6 MHz.

Continued from page 69

was found from $(K_f^2 - 1)C_{tmin} = 6.0573$. The varactor diode can be chosen from the following parameters: $C_{var\,min}$ ($C_{tmin} - C_p$) and K_c (K_f^2). Based on these parameters, a model MA4ST330 dual-varactor device was chosen with the following parameters per diode: $C_{var\,min} = 6$ and $C_{var\,max} = 26$. The parameters for the packaged device are Ls = 1.6 nH, $C_{pp} = 0.15$ pF, $R_{smin} = 0.75\ \Omega$, $R_{smax} = 0.8\ \Omega$, $C_{v\,min} = 0.5C_{var\,min}$, $C_{v\,max} = 0.5C_{v\,max}$, $C_{v\,max} = 13$ pF, $C_{v\,min} = 3$ pF, $K_{cv} = C_{v\,max}/C_{v\,min} = 4.3333$. The SRF for the specified varactor can be checked by $SRF_{v\,min} = 5.0329 \times 10^3/(L_s \times C_{v\,max})^{0.5} = 1.1035 \times 10.^3$

When the SRF is too close to F_{max}, another varactor diode must be chosen. The effective maximum varactor capacitance is:

$$C_{ve\,max} = 2.5 \times 10^8 \times C_{v\,max}/2.5 \times 10^8 - \pi^2 \times F_{min}{}^2 L_s C_{v\,max}$$

The effective minimum varactor capacitance is:

$$C_{ve\,min} = 2.5 \times 10^8 \times C_{v\,min}/2.5 \times 10^8 - \pi^2 F_{max}{}^2 L_s C_{v\,min}$$

With values of 3.3468 pF for $C_{ve\,min}$, 15.4771 for $C_{ve\,max}$, $\Delta C_{ve} = C_{ve\,max} - C_{ve\,min}$, and $\Delta C_{ve} = 12.1303$.

The required capacitance of the series capacitor can be calculated from:

$$C_{sc} = (C_{ve\,max} + C_{ve\,max})\Delta Cr/2\ (\Delta C_{ve} - \Delta Cr)\{1 + [4C_{ve\,max}C_{ve\,min}(\Delta C_{ve} - \Delta C_r)]/[\Delta C_r(C_{ve\,max} + C_{ve\,min})^2]\}$$

$$C_{sc} = 16.5756$$

Since the resonant tank must be constructed with real-world components, it is necessary to choose a component with the closest standard value. If C_s is a complex number, it is better to choose a component with a slightly large value, such as $C_{sc} = 18$ pF. The resulting capacitance of the varactor and the series capacitor can be found from $C_{vsmax} = C_{vemax}C_{sc}/\ C_{vemax} + C_{sc}$ and $C_{vsmin} = C_{vemin}C_{sc}/\ C_{vemin} + C_{sc}$, with $C_{vsmax} = 8.3218$ pF and $C_{vs\text{-}min} = 2.8221$ pF.

If the trace inductance (L_t) has a value of 1 nH, its effect on the resulting capacitance is:

$$C_{vse\,min} = |2.5 \times 10^8 C_{vs\,min}/2.5 \times 10^8 - \pi^2 F_{max}{}^2 L_t C_{vs\,min}|$$

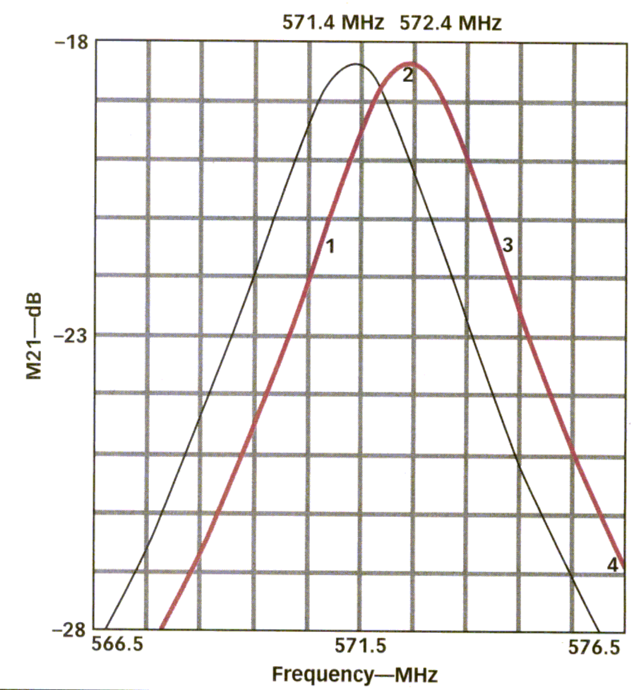
$$C_{vse\,max} = |2.5 \times 10^8 C_{vs\,max}/2.5 \times 10^8 - \pi^2 \times F_{min}{}^2 L_t C_{vs\,max}|$$

with $C_{vse\,min} = 2.9281$ pF and $C_{vse\,max} = 8.86$ pF.

The SRF of the varactor circuit can be checked according to $SRF_{min} = 5.0329 \times 10^3/(L_t C_{vse\,max})^{0.5} = 1.6908 \times 10^3$.

If the SRF is too close to F_{max}, it may be necessary to reduce the trace inductance or the series-correction capacitance, C_{sc}. The capacitance range of the varactor with the series capacitor is $\Delta C_{vs} = C_{vse\,max} - C_{vse\,min} = 5.9319$ pF. The inductance required for the desired capacitance range is $L = (2.533 \times 10^7)/\Delta C_{vs}[(1/F_{min}{}^2) - 1/F_{max}{}^2)] = 9.9514$ nH. Ten nH is the closest standard or double-varactor value to this. The capacitance of the parallel correction capacitor, C_{pc}, can be calculated by $C_{pc} = (2.533 \times 10^7/F_{max}{}^2L) \times C_p \times C_{vsemin} = 1.8682$ pF. The closest standard value is 1.8 pF.

Once these component values have been established, it is simply a matter of reviewing the expected performance parameters using the design equations within MathCAD. The required total tank capacitance can be found from the values of $C_{tmax} = 2.533 \times 10^7/F_{min}{}^2L = 13.6993$ pF and $C_{tmin} = 2.533 \times 10^7/F_{max}{}^2L = 7.7962$ pF.



Markers				
Frequency (MHz)	570.793278	572.424177	574.068104	576.50
M21—dB	−21.33881	−18.34869	−21.34268	−26.85892

Fig. 9 These linear simulation results show an upper frequency of F max = 572.5 MHz using the LINC2 program.

The resonant tank's obtained capacitance is found from $C_{max} = C_{pc} + C_p + C_{vse\,max} = 13.66$ pF and $C_{min} = C_{pc} + C_p + C_{vse\,min} = 7.7281$ pF. The tuning range obtained from these values has the following upper and lower bounds according to $F_{max} = 5.0329 \times 10^3/(LC_{min})^{0.5} = 572.509$ MHz and $F_{min} = 5.0329 \times 10^3/(LC_{max})^{0.5} = 430.6196$ MHz. The K_v factor can be found from $\Delta F = F_{max} - F_{min} = 141.8895$ MHz, with $\Delta V = V_{th} - V_{tl} = 2$ V, and $K_v = \Delta F/\Delta V = 70.9447$ MHz/V. The upper-frequency margin can be found from $m = F_{max} - F^1 = 22.509$ MHz. The lower-frequency margin can be found from $m = F_{min} - F_2 = 19.3804$ MHz.

The Q for the varactor/capacitor circuit can be found by assuming a Q of 300 for the correction capacitor: $C_{pce} = C_{pc} + C_p$, with $Q_{pce} = 300$. The value of $\omega_{min} = 2\pi F_{min}10^6$, while the value of $\omega_{max} = 2\pi F_{max}10^6$. So, for the varactor diodes, the Q can be calculated by $Q_vF_{min} = 1/(\omega_{min}C_{v\,max}10^{-12}R_{smin} = 37.9073$ and $Q_vF_{max} = 1/(\omega_{max}C_{v\,min}10^{-12}R_{smax} = 115.8315$.

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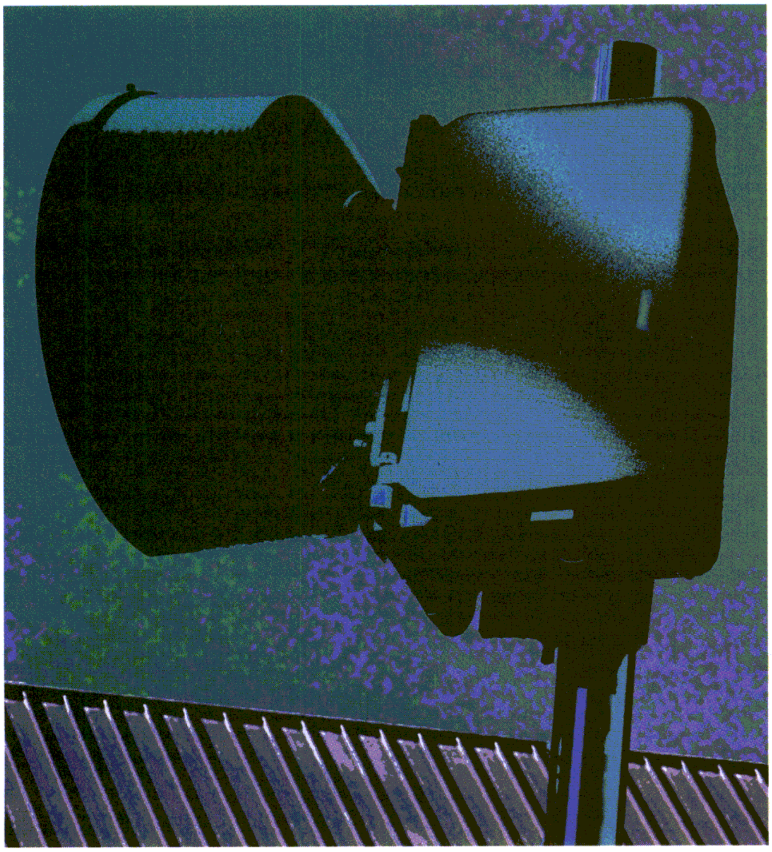

Generation II YIG-Based Synthesizers

Micro Lambda, Inc. a leader in the development of next-generation YIG devices introduces the second generation of YIG-Based Frequency Synthesizers covering the 2-12 GHz frequency range. Designed specifically for Digital Radio ODU's and harsh commercial environments, these latest synthesizers offer dual RF outputs and/or Internal Crystal reference oscillators yielding excellent integrated phase noise characteristics over carrier offset frequencies from 10 kHz to 10 MHz.

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Continued from page 74

The effect of the parasitic inductance L_s on varactor Q can be calculated by:

$$Q_{v1}F_{min} = |(\omega_{min}L_s \times 10^{-9} - 10^{12}/\omega_{min}C_{v\,max})/R_{s\,min}|$$

$$Q_{v1}F_{max} = |(\omega_{max}L_s \times 10^{-9} - 10^{12}/\omega_{max}C_{v\,min})/R_{s\,max}|$$

where:

$Q_{vl}F_{min} = 32.1351$ and
$Q_{vl}F_{max} = 108.6371$

By knowing the resistance of the PCB trace, its Q can be found. If the PCB trace has a length (l) of 1 mm, a width (w) of 0.3 mm, and thickness (t) of 0.051 mm, its minimum and maximum AC resistances can be calculated by:

$$R_{acmin} = 2.61 \times 10^{-4}(F_{min})^{0.5}l/2(w + t) = 7.7153 \times 10^{-3}$$

$$R_{acmax} = 2.61 \times 10^{-4}(F_{max})^{0.5}l/2(w + t) = 8.896 \times 10^{-3}.$$

The DC resistance value of 1.1269×10^{-3} ω can be calculated by the expression $Rl = 1.7241 \times 10^{-5}l/wt$.

The Q for the PCB trace can then be calculated by:

$$Q_{lt\,min} = \omega_{min}Lt \times 10^{-9}/Rl$$
$$Q_{lt\,max} = \omega_{max}Lt \times 10^{-9}/Rl$$

with $Q_{ltmin} = 350.69$ and $Q_{ltmax} = 404.3595$.

Then, the effect of the PCB trace on the varactor Q can be calculated by:

$$Q_{ve}F_{min} = |Q_{lt\,min}Q_{v1}F_{min}(\omega_{min}^2 \times L_t10^{-9}C_{ve\,max}10^{-12} - 1)/Q_{lt\,min} + \omega_{min}^2L_t10^{-9}C_{ve\,max}10^{-12}Q_{vl}F_{min}|$$

$$Q_{ve}F_{max} = |Q_{lt\,max}Q_{v1}F_{max}(\omega_{max}^2L_t10^{-9}C_{ve\,min}10^{-12} - 1)/Q_{lt\,max} + \omega_{max}^2 \times L_t10^{-9}C_{ve\,min}10^{-12}Q_{v1}F_{max}|$$

With $Q_{ve}F_{min} = 28.2014$ and $Q_{ve}F_{max} = 102.737$.

The Q that includes the varactors and the series capacitance can be calculated by:

$$Q_{vs\,max} = Q_{ve}F_{max}Q_{sc}(C_{ve\,min} + C_{sc})/Q_{ve}F_{max}C_{ve\,min} + Q_{sc}C_{sc}$$

$$Q_{vs\,min} = Q_{ve}F_{min}Q_{sc}(C_{ve\,max} + C_{sc})/Q_{ve}F_{min}C_{ve\,max} + Q_{sc}C_{sc}$$

With $Q_{vs\,min} = 48.5276$ and $Q_{vs\,max} = 114.5457$.

The total Q, including the varactors and the series and parallel capacitors, can be calculated by:

$$Q_cF_{max} = Q_{vs\,max}Q_{pce}(C_{vs\,min} + C_{pce})/Q_{vs\,max}C_{pce} + Q_{pce}C_{vs\,min}$$

$$Q_cF_{min} = Q_{vs\,min}Q_{pce}(C_{vs\,max} + C_{pce})/Q_{vs\,min}C_{pce} + Q_{pce}C_{vs\,max}$$

With $Q_cF_{min} = 69.9883$ and $Q_cF_{max} = 187.5641$.

This worksheet enables quick analysis for tank parameters versus values of inductor L. The results of this analysis are shown in the table, where the required tuning range is feasible for inductances starting at approximately 4.5 nH. Series capacitor C_{sc} is needed for inductances starting at approximately 5 nH and obtained Q Q_c for capacitive part of the tank is in the nonlinear function of inductance L.

If the tank inductor has a high Q of $QL > 10Q_c$, the values obtained for Q_c may be considered as the Q of the tank. This is not the case for chip inductors, however, where the total tank Q must be calculated from Eq. 43. For example, if the tank inductor has $Q_L = 50$, the total tank Q for a 4.7-nH inductor will be $Q_{LF\,min} = (53.4 - 50)/(53.4 + 50.0) = 25.8$.

In the case of a PCB inductor with the same 4.7-nH inductance and $Q >> Q_cF_{min}$, the minimal Q of the tank is equal to Q_cF_{min}. If the tank circuit is intended for use in a voltage-controlled-oscillator (VCO) circuit, the PCB inductor should show some improvement in phase noise, where $\Delta P_N = 10\log(53.4/25.8)^2 = 6.3$ dB. This example shows how doubling the tank's Q quadruples the improvement in VCO phase noise.

The LINC2 computer simulation program from Applied Computational Sciences (Escondido, CA; www.appliedmicrowave.com) was also used to simulate the design example as in Fig. 7. The simulation was performed considering whether the Q of the tank inductance is large enough to have a negligible effect on the total tank Q, as might be the case for printed-circuit inductors. **Figure 8** shows the plots for F_{min}, where the thick line is the result of the calculated L and C_{pc} values and the thin line is the result of the closed standard commercial L and C_{pc} values. **Figure 9** shows the plots for F_{max}, where the thick line is the result of the calculated L and C_{pc} values and the thin line is the result of the closed-standard commercial L and C_{pc} values.

From the simulation results, it is apparent that good design tolerance was achieved for the calculated component values. For the closest standard component values, the result is very close (approximately 0.44 percent) to the given value for F_{min} and only 0.14 percent off for F_{max}. For the Q, the F_{min} tolerance is approximately 10 percent and at F_{max}, the tolerance is approximately 7 percent. This level of accuracy can be considered sufficient for the majority of practical applications. It compares favorably with most circuit simulators and is exceeded only by electromagnetic (EM) simulation tools.

Using these analysis methods allows designers to achieve accurate results in a more convenient method than using CAE simulations. The result is a considerable savings in design time and effort. In conjunction with this method, CAE tools can be used for design verification, tolerance evaluation, and statistical Monte-Carlo analysis.

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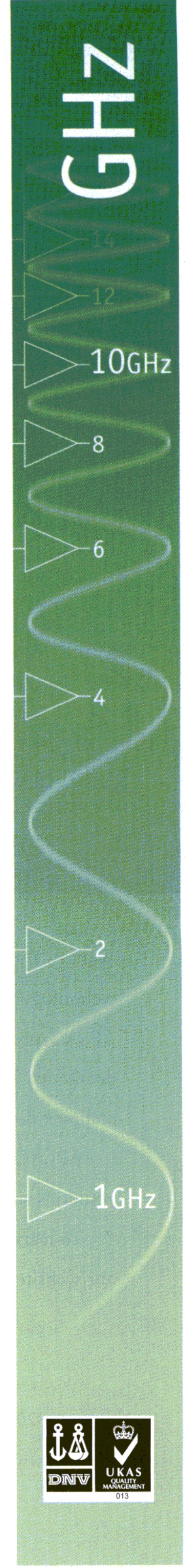

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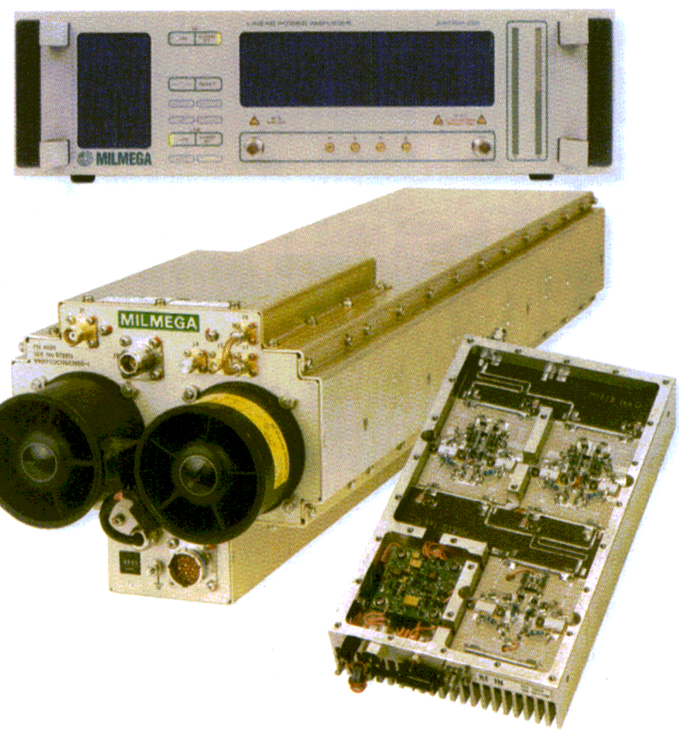

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Making ACPR Measurements

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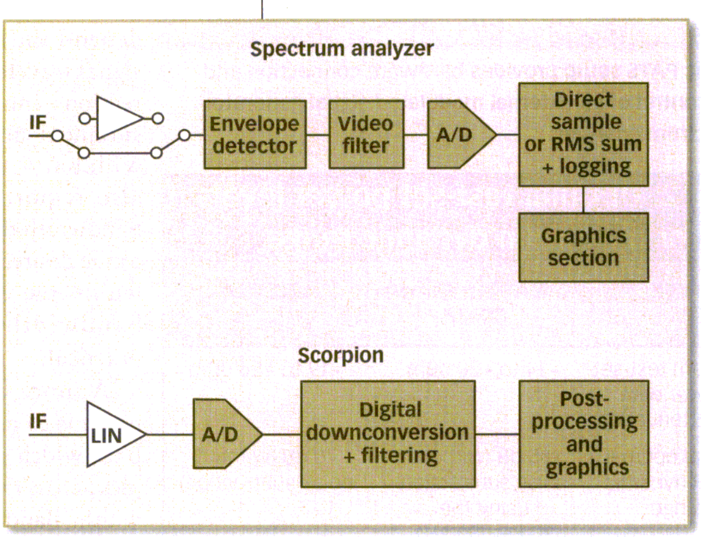
Adjacent-channel power ratio (ACPR) is a parameter that is increasingly important in the characterization of wireless communications systems employing complex modulation formats. Last month, this article series commenced with an introduction to ACPR measurements and why they are useful in determining the effects of amplifier and other component nonlinearities on the performance of digitally modulated communications systems. The task at hand involves assembling a test system with the capabilities of accurately evaluating ACPR for narrowband and wideband wireless communications systems.

A key decision in constructing an ACPR measurement system has to do with the receiver (Rx). Spectrum analyzers have traditionally been used for these types of measurements, although vector network analyzers (VNAs) can also be used.



2. Spectrum analyzers and VNAs (the Scorpion) can be used for IMD and ACPR measurements.

In a traditional spectrum analyzer, an envelope detector or similar circuit is used to extract a single amplitude value at each frequency during the final downconversion step. In some Rxs and VNAs, such as the Scorpion system from Anritsu (Morgan Hill, CA), the final downconversion/detection stage follows the analog-to-digital conversion (ADC). **Figure 2** shows a comparison of the placement of the ADC in the two architectures.

If the spectrum analyzer uses the logarithmic amplifier path, a number of errors can be introduced on modulated signals: 1. video averaging in the log domain is different from in the linear domain [equivalent for a continuous-wave (CW) tone] and 2. the noise power is quite different from the average noise level. The analyzer's video bandwidth should be kept several times larger than the resolution or intermediate-frequency (IF) band-

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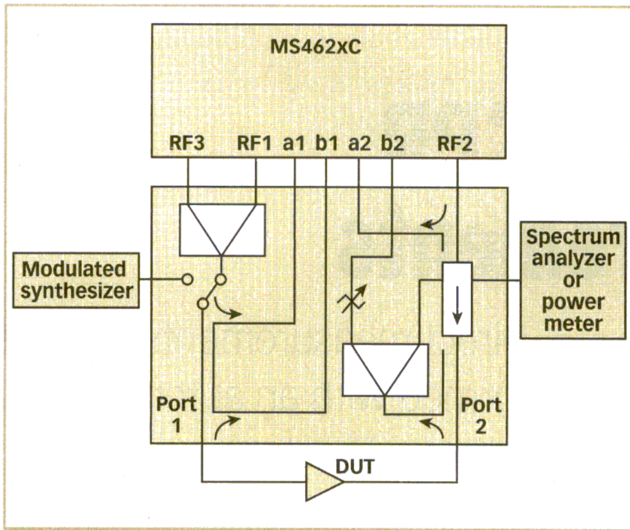
width to avoid these problems. Sweep-to-sweep averaging may help to reduce jitter in the spectrum-analyzer data, but averaging can also cause problems with noise-like signals in that averaging may be performed on logged values. Modulation-specific corrections can be applied, but the process is somewhat complicated

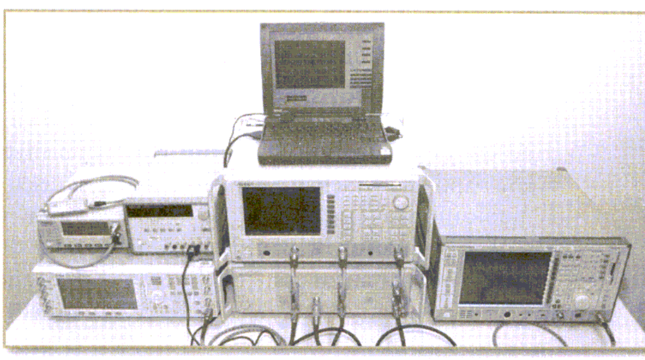
A better solution is to acquire multiple samples per frequency point (for a single sweep or over several sweeps) and root-mean-square (RMS) average them in a linear sense. This avoids the distortions and corrections discussed earlier, assuming enough statistically independent points are obtained. Some spectrum analyzers and the internal PATS/Scorpion Rx scheme used in the Scorpion-based Power Amplifier Test System (PATS) from Anritsu implement this latter approach. In a true ACPR measurement, however, it is a ratio of two powers that is critical so that some of the disadvantages of the older technique previously described may not apply.

In performing ACPR measurements, image and spurious Rx responses must be considered. While not an issue in most spectrum analyzers, these responses can affect the accuracy of a VNA system since these Rxs are optimized for speed and are often double sideband in nature. Response corrections in a VNA are normally provided either in instrument or test-system software.

The Scorpion VNA is an example of a double-sideband Rx. Due to this, care must be taken in handling the internal local-oscillator (LO) positioning and intermediate-frequency (IF) control. Adjustments depend on the channel bandwidth relative to the nominal system IF of 125 kHz and the frequency scale of variations, and can be used to remove main image effects.



3. This block diagram shows the standard configuration of a PATS.



4. The basic PATS setup provides hardware connection and software control of an external modulated signal generator and a spectrum analyzer.

Table 2: Optimal test-set power levels for maximum dynamic range

TYPE	NARROWBAND CDMA	WCDMA
Optimum test-set power with 0-dB attenuation	+14 to +20 dBm	+19 to +26 dBm
Typical optimal ACPR dynamic range	85 dB (without noise subtraction) using the 30-kHz/30-kHz definition	70 dB (without noise subtraction)

The internal LO should always be positioned away from the main-channel bandwidth when making adjacent- or alternate-channel measurements. When the channel width is comparable to or larger than the image spacing, two passes of measurements should be made over the desired range at different LO spacings so that the image contributions can be isolated and removed. The resulting residual error, after the automatic corrections, is quite small (normally much less than 0.1 dB).

Either a spectrum analyzer or a VNA can perform a measurement over a specific bandwidth, although different approaches exist for power measurements. With a wide-bandwidth Rx, the entire measurement bandwidth could be sampled at once for a fast measurement, although this may be difficult with very wideband systems such as wideband code-division multiple access (WCDMA). By using a single instantaneous power measurement, the accuracy depends on the shape of the spectrum and the instrument's filter shape. While corrections can be made (the corrections depend on the modulated signal waveform), these corrections can increase measurement uncertainty. The wideband test approach also requires a resolution bandwidth that is very close to the desired channel bandwidth; the exact match of bandwidths may not be practical.

A more common technique is to use a smaller Rx bandwidth and take samples across the desired bandwidth. Bandwidth selection is critical. If a too-narrow

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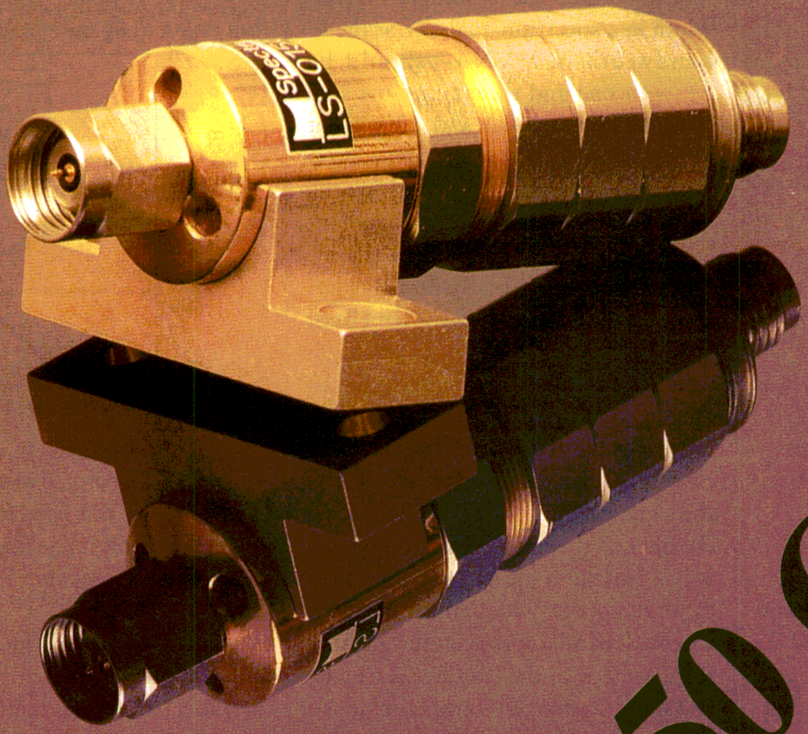
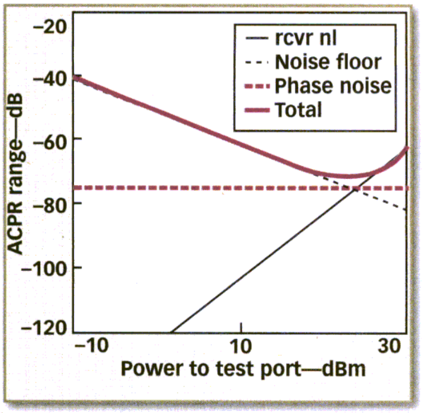




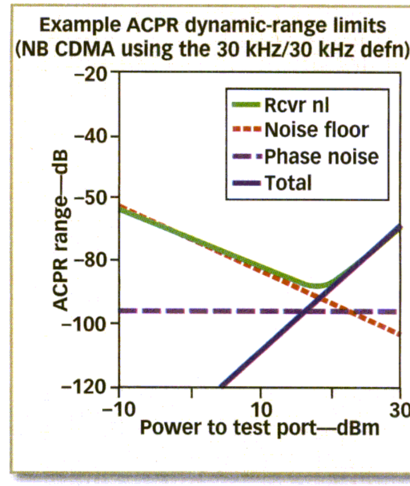
5. The PATS/Scorpion measurement configuration was used to create this plot of dynamic range for wideband CDMA measurements.

Continued from page 80

bandwidth is selected, either the signal will be inadequately sampled or the measurement will take too long. If a too-wide bandwidth is selected, there will be measurement error at the channel-band edges.

Generally, the measurement bandwidth—either the resolution bandwidth in a spectrum analyzer or the IF bandwidth in a VNA—should be between one and three times the step size and between 0.1 and 10 percent of the channel bandwidth. This latter ratio will change depending on the density of the data points and the limitations of the test bandwidth.

Although the broadband-measurement approach provides the benefit of speed, the narrowband approach offers many other advantages. It can adapt quickly to different types of signals. The wideband technique must match the Rx bandwidth closely to the signal of interest. The shape of the Rx filter in the narrowband approach is less critical to measurement accuracy than in the wideband approach. The wideband approach must correct for the shape of the Rx filter. The narrowband approach can trade speed for jitter, and can make band-edge corrections more easily than the wideband approach. For many of the reasons shown and due to the flexibility of the Rx, this article will focus on the narrowband method.



6. The PATS/Scorpion measurement configuration was used to create this plot of dynamic range for narrowband CDMA measurements.

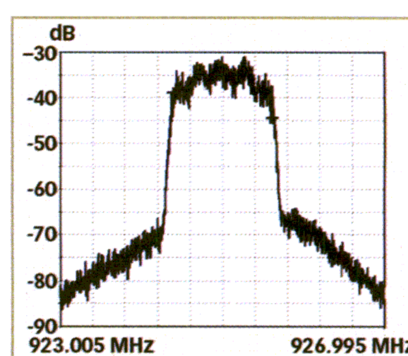
Although it is of less importance in the narrowband approach, the measurement filter shape must at least be considered. Most of the standard specifications dictate a particular Rx filter shape (e.g., Gaussian, root-raised cosine, etc.) to properly emulate how the devices under test (DUTs) will actually be used. Most modern instruments have a provision for digitally setting the most common filter varieties, although the impact on ACPR measurements is often small.

An integrated test system can help to improve test times, optimize

Continued on page85

Table 3: Comparing measurement receivers

ISSUE	SPECTRUM ANALYZER	VNA
Logamps in IF	Often present, can cause errors with most digitally modulated signals. Can be disabled in some instruments.	Not used
Averaging, sampling	Point-by-point averaging does not improve jitter. Can introduce errors if done after logamp. Sweep-to-sweep averaging can reduce jitter. Instantaneous sampling yields high jitter, although RMS sampling can help.	Point-by-point averaging does not improve jitter. Sweep-by-sweep averaging can reduce jitter (in RMS sense). Final downconversion is often performed digitally, supporting the use of RMS sampling.
Images and spurious	Usually not an issue	Must be corrected
Dynamic range	Depends on receiver noise floor, nonlinearities, and internal phase noise. Nonlinearities often critical.	Depends on receiver noise floor, nonlinearities, and internal phase noise. Noise floor usually critical.
Video bandwidth and smoothing	Video bandwidth must be large, relative to resolution bandwidth. A problem after logging.	Effective smoothing functions. Bandwidth must be large, relative to the IF bandwidth.



7. This ACPR measurement was performed for the sample amplifier with narrowband CDMA test signals at a single power level.

Continued from page 82

designs, and improve large-signal performance. The PATS is such a system, designed to enable many of the common PA tests with a single connection. In the standard configuration, measurements such as S-parameters, compression, intermodulation distortion (IMD), and some hot S-parameters can be performed. Switches and connections are in place for use with a modulated source (not integral to the Scorpion VNA) required for ACPR measurements **(Fig. 3)**. The PATS software provides control for a variety of signal sources from several different manufacturers. The basic PATS configuration also supports connection of a spectrum analyzer or external receiver in addition to the Scorpion VNA **(Fig. 4)**.

The dynamic measurement range limit can be found by computing the port-referred Rx noise floor, phase-noise contribution, and Rx-nonlinearity contribution. This calculation will depend on the channel bandwidth (since this directly affects the noise contributions), as well as the statistical nature of the modulated waveform (since this affects the Rx nonlinearities). In some cases, the Rx noise-floor contribution can be reduced by carefully subtracting out its contribution to the measured result. Since the most challenging measurements to date are WCDMA

Continued on page 86

Table 4: Comparing adjacent- and alternate-channel measurements

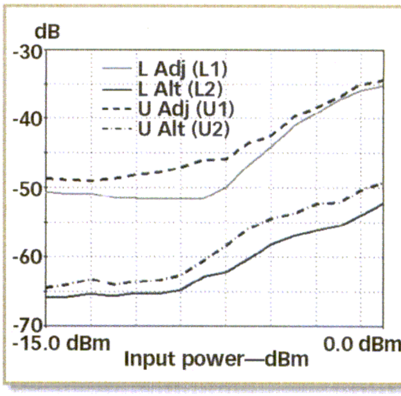
POWER LEVELS	CHANNEL/ INSTRUMENT	CARRIER FREQUENCY 887 MHz	905 MHz
Input = –10 dBm	Adjacent/SA	–50.5 dB	–47.9 dB
Output = +18 dBm	Adjacent/VNA	–50.4 dB	–47.9 dB
	Alternate/SA	–64.9 dB	–63.7 dB
	Alternate/VNA	–64.6 dB	–63.8 dB
Input = –5 dBm	Adjacent/SA	–43.8 dB	–42.7 dB
Output = +23 dBm	Adjacent/VNA	–44.0 dB	–42.5 dB
	Adjacent/SA	–56.0 dB	–54.9 dB
	Adjacent/VNA	–55.9 dB	–55.1 dB
Input = 0 dBm	Adjacent/SA	–35.0 dB	–34.9 dB
Output = +28 dBm	Adjacent/VNA	–35.2 dB	–35.2 dB
	Adjacent/SA	–50.6 dB	–49.8 dB
	Adjacent/VNA	–51.0 dB	–49.6 dB

Continued from page 85

with its large channel bandwidth, this calculation will be presented first.

The following calculations assume a PATS setup with a Scorpion VNA as the test Rx, although a similar analysis can be performed for any Rx. A standard PATS test set is also assumed. If a different test set is used, the input-power axis must be scaled by the difference in test-set loss from the port-2 connector to the b2 input port on the Scorpion VNA. One WCDMA configuration (channel bandwidth of 3.84 MHz) was used in the calculation along with typical PATS/Scorpion parameters. It was also assumed that the 30-kHz IF bandwidth setting was not used so that gain ranging would be enabled to increase the dynamic range of the Rx.

Three different noise components were summed on a linear power basis to create a composite curve **(Fig. 5)**. As expected, the thermal noise floor dominates at lower input-signal levels while Rx nonlinearities dominate at higher levels. For this particular setup, a dynamic range of 63 dB can be obtained over an input-power range of approximately +12 to +30 dBm and about 70 dB of dynamic range can be obtained for input powers of +19 to +26 dBm.



8. This ACPR measurement was performed for the sample amplifier with narrowband CDMA test signals at swept power levels.

A similar calculation was made for for narrowband CDMA **(Fig. 6)**. The only difference was in the integration bandwidth and the effect of Rx nonlinearities (since the peak-to-average power ratio is different). Since the channel bandwidth is narrower, the noise-floor contributions are reduced and the Rx nonlinearities become a more significant issue. As a result, the optimal range drops in power (to slightly below +20 dBm into the test set with this attenuator setting) but the best dynamic range improves considerably. The ACPR definition using a 30-kHz sample in the middle of the main channel was defined for this calculation.

Table 2 summarizes optimal test-set

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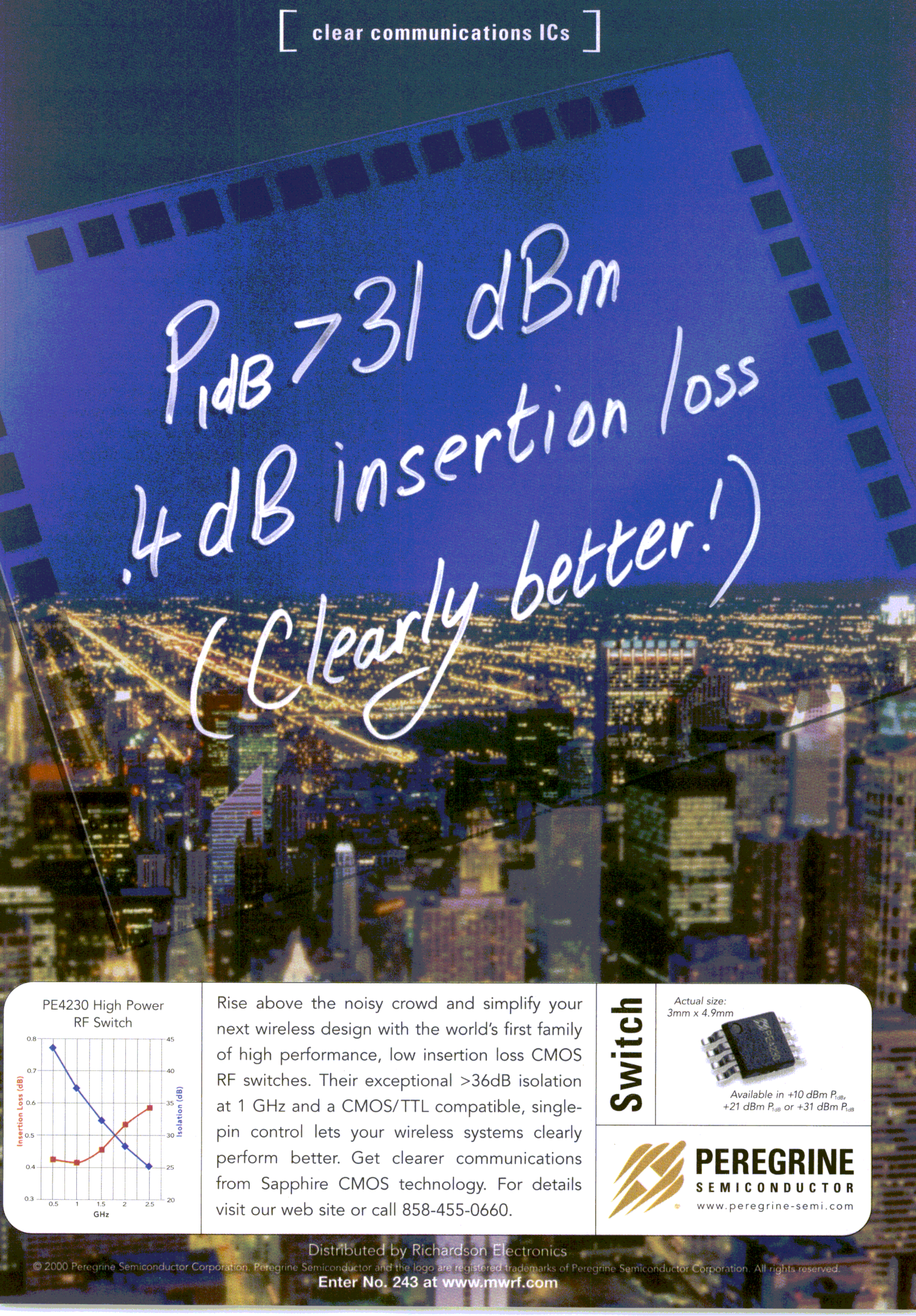

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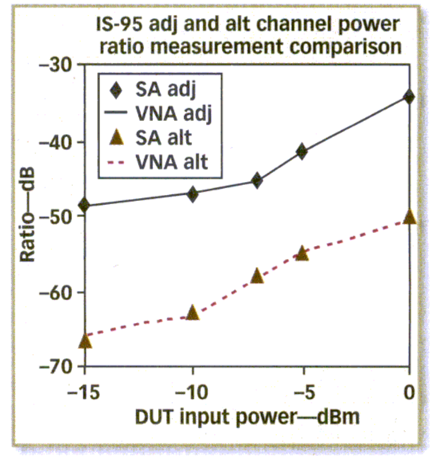

9. These plots compare narrowband-CDMA ACPR and alternate power measurements with a spectrum analyzer and VNA at a carrier frequency of 925 MHz.

Continued from page 86

power levels and dynamic ranges based on these two experiments. Table 3 summarizes the expectations of the different receiver types, specific to the architectures of **Fig. 2**.

In order to evaluate the different measurement approaches, a sample measurement was performed on a typical CDMA driver amplifier. The amplifier has nominal output power of +26 dBm and typically 25-to-30-dB gain. It was evaluated with IS-95 (CDMA) tests of ACPR and alternate-channel power ratio (30-kHz bandwidths at offsets of 885 and 1980 kHz, respectively) for a main channel bandwidth of 1.23 MHz. Measurements were made with an input signal having a pilot tone (Walsh code 0), paging tone (Walsh code 1), synch tone (Walsh code 32), and six traffic channels (Walsh codes 8 through 13). More information on Walsh codes can be found in reference 8.

The Walsh codes in a test signal (and their associated power contributions) affect the power statistics presented to the DUT and, hence, affect the nonlinearities and distortion produced by the DUT. With measurements performed at a variety of input-power levels ranging from 215 to 0 dBm, ACPR levels are expected to fall

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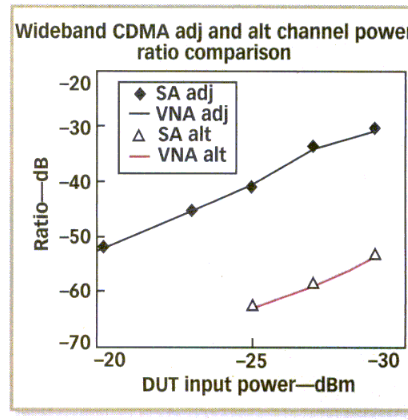
in the 240-to-250-dBc range when using the 1.23-MHz main definition and 225 to 235 dBc when using the 30-kHz main definition). Measurements of the alternate-channel power ratio are expected to fall in the 260-to-270-dBc range for the 1.23-MHz main definition and 245 to 255 dBc using the 30-kHz main definition.

Figure 6 provides results for IS-95 measurements with the 30-kHz (narrowband) definition. Based on the expected results, these measurements



10. These plots compare WCDMA ACPR and alternate power measurements with a spectrum analyzer and VNA at a carrier frequency of 1850 MHz.

will not stress the dynamic range of the PATS/Scorpion system (with probably more than 45-dB headroom in the optimal power ranges for ACPR and more than 25 dB for alternate-channel power-ratio measurements). The optimal power range for this test system (based on Fig. 6) would be at test-port power levels of +15 to +20 dBm. Examples of measurements with a single power level and swept power are shown in **Figs. 7** and **8**, respectively.

Since the PATS enables connection of a spectrum analyzer, as well as a VNA, it might be interesting to compare results of ACPR measurements performed using the two approaches. In performing these correlation studies, some basic guidelines should be followed. For example, the signal source should be set up exactly the same way for both sets of measurements (with the same channel allocations, etc.). The DUT should see a comparable impedance match in the two approaches. Both Rxs should be set for the optimum locations (in terms of input power and attenuation) in their dynamic ranges. The appropriate measurement bandwidths (channel bandwidths and resolution/IF bandwidths) should be selected for both approaches, and the jitter levels should be sufficiently low in both cases.

When performing these measurements with the PATS, the match will be the same for the two measurements, since the DUT interfaces with the same coupler/splitter assembly all the time. The spectrum analyzer was set up (through its default settings for IS-95) with a resolution bandwidth of 30 kHz, a video bandwidth of 300 kHz, no logamp, and a reference-level setting of +210 or +220 dBm (for the high and low input-power levels, respectively). The Scorpion VNA was set up with an IF bandwidth of 1 kHz, no trace smoothing (but with trace-to-trace RMS averaging), and the PATS attenuator settings listed previously. Little difference was observed using an IF bandwidth of 3 kHz in this particular case.

The narrowband CDMA test comparison is shown in **Fig. 9** for the higher-level adjacent and alternate channels with a carrier frequency of 925 MHz, with two other carrier frequencies shown in Table 4. The maximum difference was approximately 0.5 dB. Since each instrument exhibited jitter of approximately 60.6 dB, this agreement seems reasonable.

For WCDMA, a second correlation example was run, with a different DUT. As in the earlier example, the spectrum analyzer is connected to the PATS test-set access port so that the DUT experiences a consistent impedance match. Since this is a WCDMA test, it is more likely to stress the dynamic ranges of the Rxs. The spectrum analyzer was set up (through default settings for this standard) with a resolution bandwidth of 30 kHz, no logamp, and a reference-level setting of +220 or +230 dBm (for high- and low-input powers, respectively). The Scorpion VNA was set with an IF bandwidth of 10 kHz (in order to use gain ranging and optimize dynamic range), no trace smoothing (but with trace-to-trace RMS averaging), and PATS attenuator settings of 0 or 10 dB (for DUT output powers above +26 dBm, an attenuation setting of 10 dB was used) based on the dynamic-range curves shown previously.

The WCDMA (measurement bandwidth of 3.84 MHz at offsets of 5 and 10 MHz) comparison is shown in Fig. 10 for the higher-level adjacent and alternate channels. The carrier frequency for this plot was 1850 MHz. The maximum difference in this case was approximately 1 dB and occurred at the lowest power levels. Jitter levels were higher in this measurement since the signals being measured were closer to the Rx noise floors. This tends to explain the

Continued on page 92

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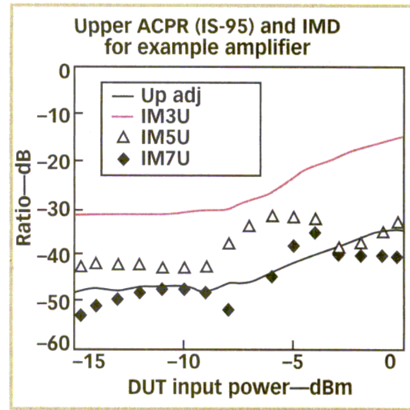
slightly larger separations in results. Alternate-channel data were not plotted for lower drive levels since these measurements were basically at the dynamic-range limits of both Rxs.

IMD Measurements

Due to the complexity of ACPR measurements, there is much interest in comparisons to two-tone IMD measurements in order to determine whether these measurements can be used in place of actual ACPR measurements. This occurred by performing an ACPR power sweep and plotting it versus an IMD power sweep (third-, fifth-, and seventh-order IMD). The same test set was used as in the earlier measurements, with IMD tone separation set at 600 kHz to approximately mimic the bandwidth used by the modulating signal.

The DUT input-power axis in **Fig. 11** refers to the tone 1 power for the IMD measurements and for the total input power for measurements performed with a modulating signal. The purpose of these comparisons is to examine the curve shape rather than the absolute values, since a lookup table can be constructed to normalize the values if the behaviors of the curves are similar. Only ACP levels for the upper **(Fig. 11)** and lower products are shown for clarity. One point of comparison is the dip in the lower third-order IMD product (IM3L), which corresponds to a slight dip in the lower ACPR results. When the third-order IMD dip is smaller on the upper sideband (IM3U), the upper ACP dip also shrinks.

The uncertainty in this measurement is almost exclusively due to the raw-power measurement. The most significant factors are dynamic-range-related errors and jitter, while less-significant factors have to do with spurious-response errors, sampling-rate and/or filter-shape-induced uncertainties, raw ADC linearity errors, impedance-match-induced errors, and other absolute-power measurement uncertainties. Since only the power ratio is of interest, proportional (absolute) power uncertainties can be ignored. The sampling-rate and/or filter-shape-induced uncertainties tend to cancel out, except for those errors incurred at the edges of the main signal. Assuming that a large-enough number of samples (a trade-off with measurement time) have been acquired, the uncertainty due to jitter can also be neglected. The signal source is also assumed to have sufficiently low ACPR (at least 10 dB below that of the DUT) so that its ACPR levels do not degrade the accuracy of the measurements.



11. These swept-power ACPR and IMD results are shown for products higher in frequency than the carrier.

Generally, ADC linearity errors are so small that they can be ignored. An exception is the unusual waveform in which clipping occurs at high peak power levels. With a standard PATS/Scorpion test set, clipping will occur near +40 dBm with 0-dB attenuation. Match-induced errors are rarely a problem, since the frequency spans are relatively small.

With these assumptions and using Scorpion as the Rx, the dominant source of uncertainty will likely be the proximity to the dynamic-range limits, along with some residual, uncorrected spurious contamination. An estimate of an uncertainty floor (far from the limits) is approximately 0.25 dB plus jitter for WCDMA (a bit less for narrowband CDMA, since image uncertainty is less of an issue). MRF

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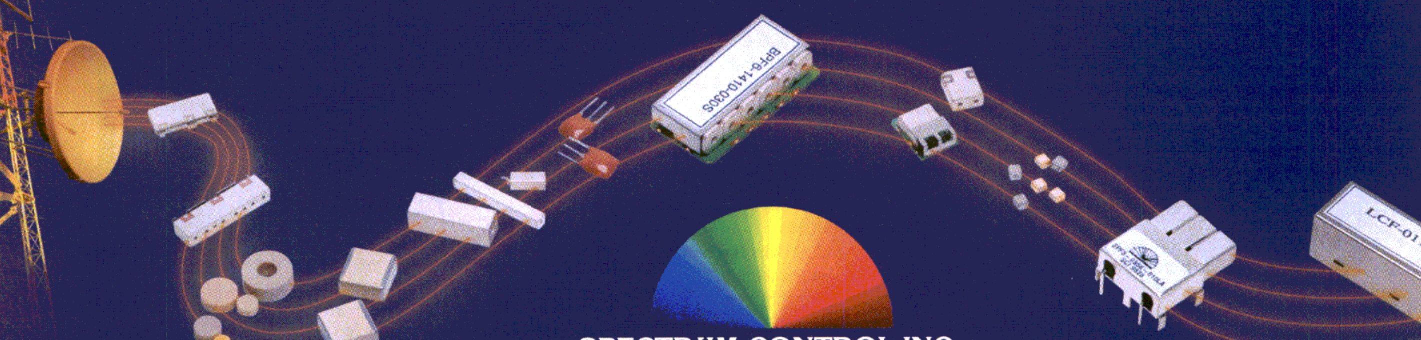

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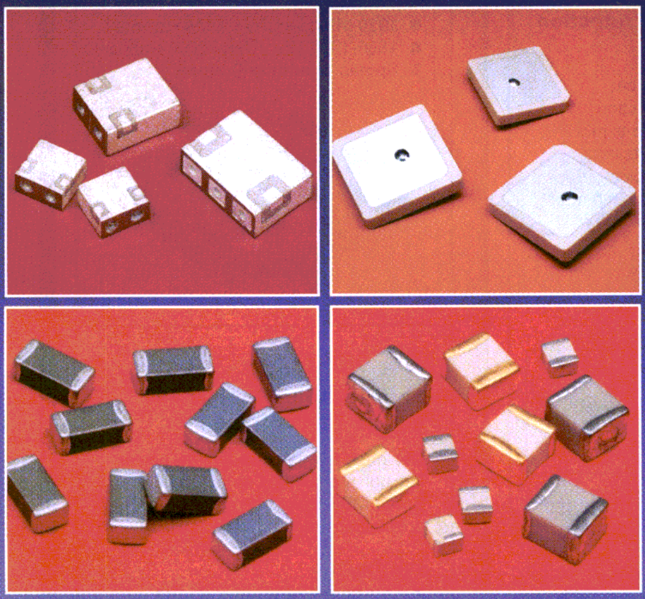

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Models Aid The Analysis Of Electronics Cooling

Computational-fluid-dynamics models help designers analyze the heat-transfer characteristics of electronics systems.

Of all the failures that occur in electronics systems, more than half are caused by overheating devices and circuits. And with ever-increasing component power densities and the drive toward greater system compactness, keeping these components and systems cool is now becoming a key packaging-design issue. In the past, thermal-design analysis involved the use of hand calculations or crude, lumped-resistor-network approaches. Computational fluid dynamics (CFD), which uses high-speed computers to solve the equations governing heat flow and transport, was the preserve of the aerospace industry. However, the increased speed and decreased costs of computers, along with improvements in numerical algorithms, have resulted in the widespread use of CFD. This technique delivers the following advantages:

- Higher accuracy.
- Visualization of complete air/fluid flow fields allows design flaws to be

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Warwick Dynamics Ltd., Unit 19, Barclays Venture Centre, Sir William Lyons Rd., Coventry CV4 7EZ, England; +44 (0)24 76 528242, FAX: +44 (0)24 76 418922, e-mail: ptg@eng.warwick.ac.uk.

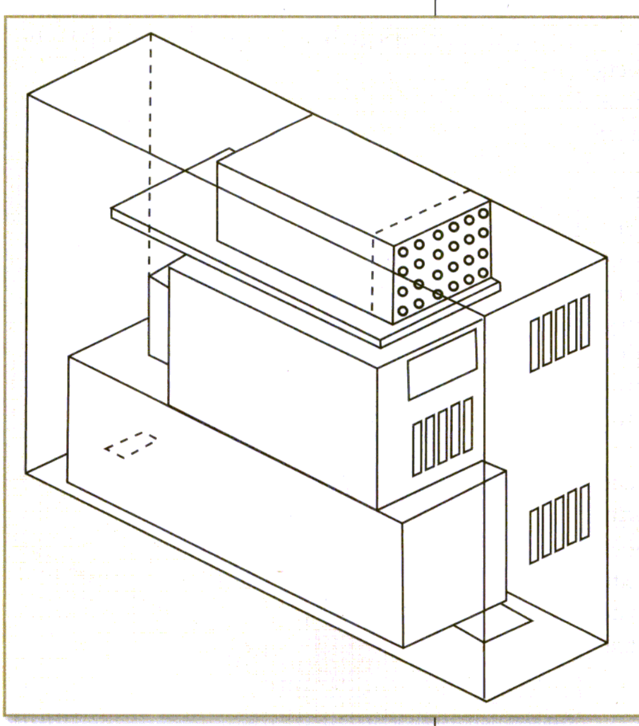

Fig. 1 The CPU of a cash-point dispenser is shown here.

Continued from page 95

readily observed and optimally corrected.

· Supports easy and relatively accurate "what-if" testing for a large number of component layouts and fan sizes. This results in better packaging designs produced in a shorter period.

· Enables exploration of extreme-climate thermal scenarios, avoiding expensive physical experiments.

· Supports study of time-varying flows and heat transport.

Using CFD in the design process can significantly improve product quality, reliability, and time to market.

Some early work on modeling idealized electronic systems grappled with the effects of time-varying heat transfer. The most notable studies in this area involved a high-accuracy CFD approach developed at the Massachusetts Institute of Technology (MIT). This research confirmed the significant influence of varying flow on electronics cooling. Recent University of Warwick projects, supported by the British Government's Engineering and Physical Sciences Research Council (EPSRC), Hewlett-Packard Corp., Digital Equipment Corp., GEC Marconi Avionics, and AT&T/NCR have begun to extend the MIT-code-based work to more realistic systems.

One of these projects dealt with heat flow in the central processor unit (CPU) of a cash-point dispenser, shown in **Fig. 1**. **Figure 2** shows vectors and contours of velocity magnitudes for various planes of the Fig. 1 geometry. **Figure 3** shows the predicted x-y plane plots of air-flow streamlines (on the left) and contours of varying levels (on the right). Around the top left-hand region of the unit, one sees flow features that vary strongly with time—the flow separates and re-attaches in what is known as a limit cycle. This cycle results in significant variability, which is consistent with subsequent measurements. There are numerous ways by which flow variability can be introduced into electronic systems and, generally, it will increase heat transfer. The best-known example is the classic Rayleigh-Bernard instability resulting from layers of cold air resting on layers of hot air. The cooler, denser air attempts to fall while the hotter, lighter air attempts to rise. This triggers variability, and increases cooling. The consideration of flow instabilities and other allied effects is important for accurate design analysis.

Motivated by the success of the research, the University of Warwick has formed a company called Warwick Dynamics Ltd. This company will develop state-of-the-art CFD code and make staff expertise widely available to industry. MRF

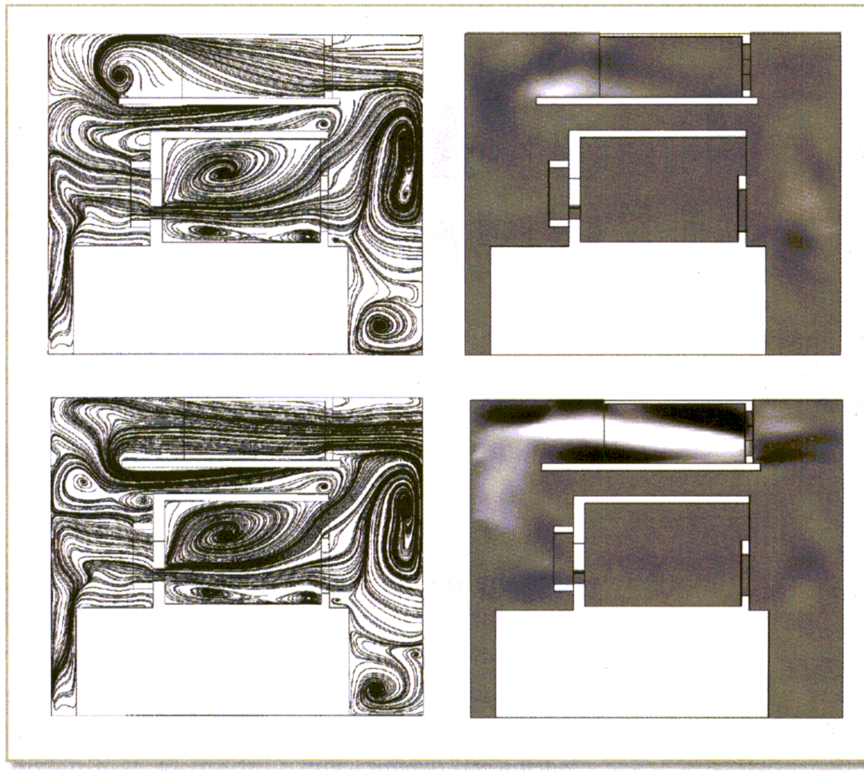

Fig. 3 The predicted x-y plane plots of air-flow streamlines are shown on the left, and the contours of varying levels are shown on the right.

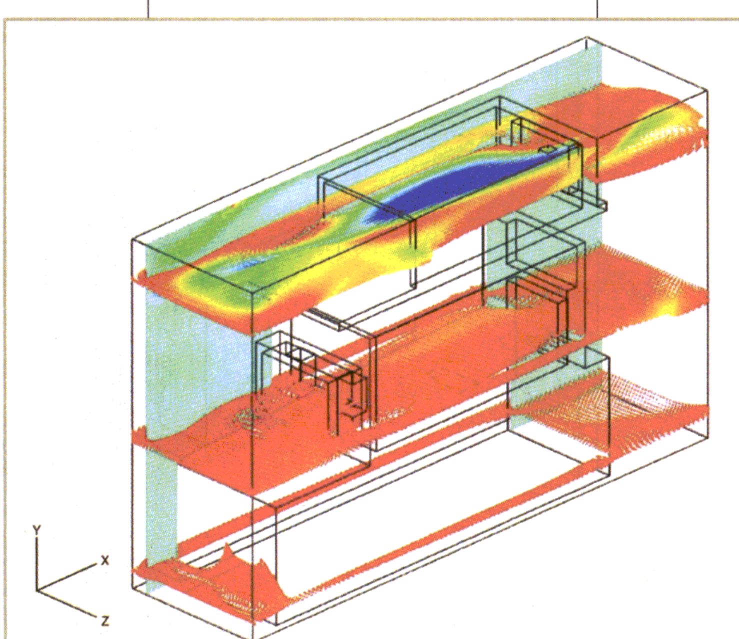

Fig. 2 The vectors and contours of velocity magnitudes for various planes of the cash-point dispenser CPU can be seen here.


W-Band
75–110 GHz
E-Band
60–90 GHz
V-Band
50–75 GHz
U-Band
40–60 GHz
Q-Band
33–50 GHz
Ka-Band
26.5–40 GHz
K-Band
18–26.5 GHz
Ku-Band
12.4–18 GHz
X-Band
8.2–12.4 GHz
C-Band
4.0–8.2 GHz
S-Band
2.0–4.0 GHz
L-Band
1.0–2.0 GHz
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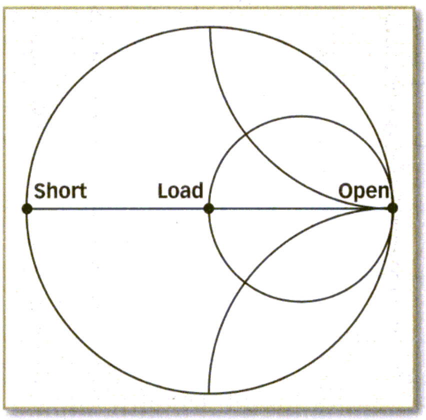
Performing S-Parameter Measurements

Proper measurement techniques and calibration methods can go a long way in evaluting the S-parameters of high-frequency, high-speed analog and digital circuits.

Understanding how different S-parameters describe the behavior of analog and digital circuits can help engineers to accelerate the development of matching networks and high-frequency, high-speed components. A critical part of that understanding is knowing how to measure the S-parameters of active and passive devices. This last installment of this four-part series on S-parameters will examine measurement techniques and discuss the importance of a good calibration.

GARTH SUNDBERG
Member of the Technical Staff, Technology, Research, and Development Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: www:maxim-ic.com.

S-parameters were developed to measure devices at high frequencies (i.e., above 1 GHz), and the vector network analyzer (VNA) was the test tool developed for the purpose of measuring the S-parameters of active and passive components and devices. Unfortunately, the connection between the VNA and the device under test (DUT) is never ideal and represents an impedance discontinuity. To accurately account for the connections between the DUT and the VNA, a calibration must be performed.



1. The Smith Chart can be used to show the impedances of calibration standards, such as shorts and opens.

Measurements are only as accurate as the equipment, methodology, and skill of the test-equipment operator. To ensure the most accurate S-parameter measurements possible, good test equipment and calibrations are required. Which calibration standards are used depends on the measurement setup. Some possible calibration standards are the short, open, load, and through (SOLT) that are provided in the Agilent model 85033D 3.5-mm calibration kit from Agilent Technologies (Santa Rosa, CA) or the impedance-standard substrate (ISS) made available by Cascade Microtech (Hillsdale, OR) for calibration of on-wafer measurements. Another option is to define a custom set of standards using SOLT techniques, through-reflect-line (TRL) methods, line-reflect-match (LRM) methods, or other calibration techniques. All calibration methods are designed to provide accurate and repeatable measure-

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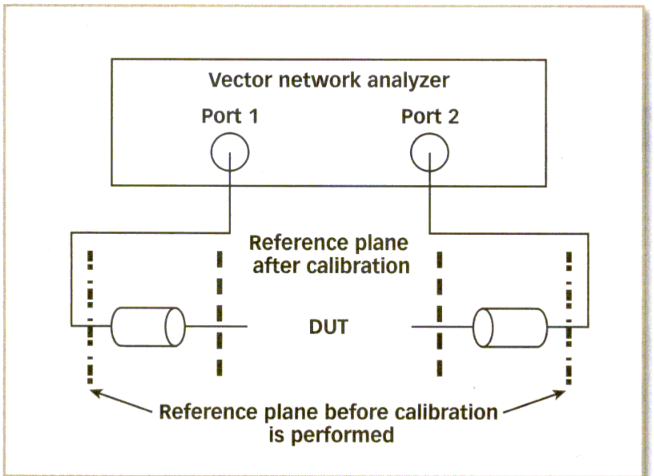


2. This block diagram shows a typical VNA-based measurement system with the reference planes defined before and after calibration.

Continued from page 99

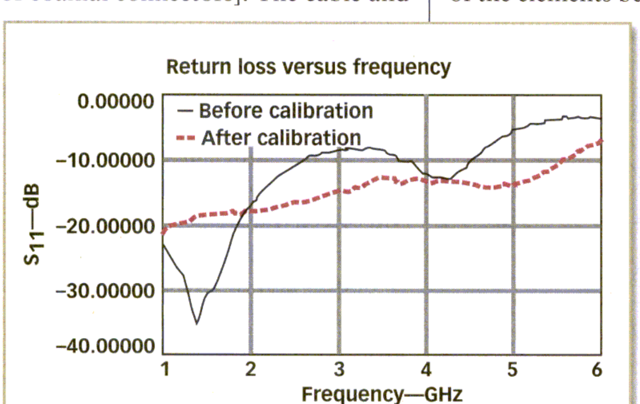
ments by removing uncertainties from the test equipment and associated hardware, such as interconnecting cables and test fixtures.

Using an analogy of optics and light to describe S-parameters, a DUT can be thought of as an object that is behind a piece of dirty glass. In order to see the object clearly, the glass must be clean. Calibration can be thought of as the process of cleaning the glass in order to provide the clearest-possible picture of the object.

In a typical VNA measurement system, coaxial cables connect the VNA to the DUT [either through surface-mount-architecture (SMA) connectors, waveguide flanges, wafer probes, or other types of coaxial connectors]. The cable and connectors have a significant effect on the measured data (think of the cables and connectors as the dirty glass). Without a calibration, the responses of the connectors and cables are being measured along with that of the DUT. A calibration is needed to remove the electrical contributions of the cables and connectors from the response of the DUT.

A calibration such as SOLT defines the position of the test setup and DUT on the Smith Chart. The open standard defines the right edge of the Smith Chart, the short standard defines the left edge of the Smith Chart, and the load defines the center of the Smith Chart **(Fig. 1)**. The through standard identifies the time delay and signal loss introduced by the test cables and connectors.

Figure 2 depicts a test setup with the reference planes defined before and after calibration. In that test setup, the transmission-line elements are everything that lies between the VNA and the DUT [i.e., cables, connectors, transmission lines on printed-circuit boards (PCBs), matching networks, etc.). If all of the elements between the VNA and the DUT are not correctly identified and calibrated out, then the measurement results will not be accurate.



3. The S_{11} performance of the MAX3875 was measured before and after calibration to show the effects of removing test cable and connector electrical contributions.

To illustrate this point, the S_{11} performance of the MAX3875 integrated circuit (IC) was measured before and after a calibration was performed. The MAX3875 is a compact, low-power clock-recovery and data-retiming IC for 2.488-Gb/s synchronous-digital-hierarchy (SDH) and Sychronous Optical Network (SONET) applications. The IC operates on +3.3 VDC. Its fully integrated phase-locked loop (PLL) recovers a synchronous signal from the serial non-return-to-zero (NRZ) data input, which is retimed by the recovered clock signal. Differential positive-emitter-coupled-logic (PECL)-compatible outputs are provided for the clock as well as the data signals, and an additional 2.488-Gb/s serial input is available for system loopback diagnostic testing. The IC also includes a TTL-compatible loss-of-lock (LOL) monitor.

The results of return-loss measurements performed on the MAX3875 before and after calibration are provided in **Fig. 3**. As can be seen, the VNA measurements performed without a proper calibration can be misleading, since the return loss shows a large drop between 1 and 2 GHz, and a large rise at approximately 3 GHz, due to the electrical contributions of the interconnecting cables and connectors in the test setup. The calibration removes the electrical contributions of the test cables and connectors used to transport test signals between the DUT and the VNA, and provides more meaningful results in terms of the AX3875's actual performance.

A calibration can also be useful in shifting the reference plane of a VNA-based test setup. Many analyzers offer built-in inverse Fast Fourier transform (FFT) capability to convert frequency-domain information to the time domain (signal responses as a function of time). Through a high-quality calibration and an analyzer's time-gating capability, the reference plane can be shifted beyond the connectors of a test fixture and to the ports of a DUT.

The final installment in this four-part article series on S-parameters has been meant to familiarize readers with measurement issues. A good calibration can be compared with taking a picture of an object through a piece of dirty glass, with the calibration being the process of cleaning the glass. MRF

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DESIGN

Automated Process Cuts Filter Tuning Time From Hours To Minutes

Fast, efficient tuning of S-, C-, and X-band filters reduces production time and cost for Army missile systems.

JOHN E. REINHARDT, ANDREW V. FOGLE, DONALD E. DUNSTONE
US Army Aviation and Missile Command, Redstone Arsenal, AL 35898-5270; (256) 842-7655, e-mail: John.Reinhardt@rdec.redstone.army.mil

At radio frequencies in the range of S-, C-, and X-band (2.6 to 12.4 GHz), manual tuning of lumped inductive-capacitive (LC) filters is cumbersome and time-consuming at best. But an Army Manufacturing Technology (ManTech) program has developed an automated process for tuning these filters. The tuning process is faster—less than 10 minutes—than manual tuning (up to 2 hours). The associated fabrication processing time has also been reduced, from more than 12 hours to less than 4 hours.

In the gigahertz band, components are quite small and tuning methods, such as using a tuning slug in a wire-wound inductor, do not work well. The size of a gigahertz wire-wound inductor is approximately the same size as the lead in an ordinary pencil. Producing a precise slug and installing it can be difficult. The tuning of high-frequency filters is accomplished typically by "physically spreading or closing the distance between turns of a coiled-wire inductor or snipping the length of a pair of twisted wires whose inter-wire capacitance is one of the filter elements."[1]

The standard approach (the baseline approach) to filter tuning prior to this project was to physically spread or close the distance between turns of a coiled-wire inductor. This method

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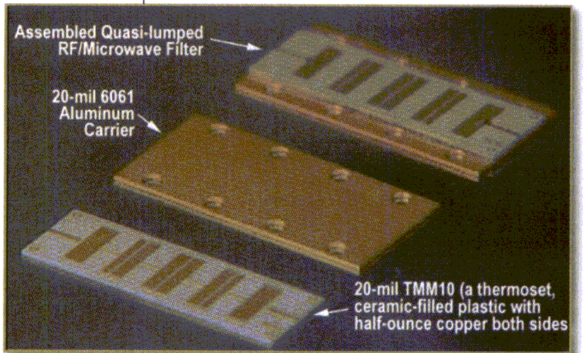

Fig. 1 A quasi-lumped RF/microwave filter replaces the conventional coil-wire inductor type in the automated tuning system.

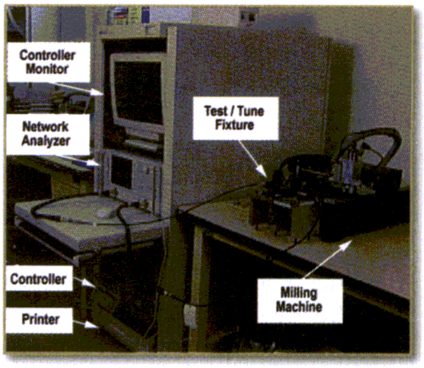

Fig. 2 The automated tuning station can trim, tune, measure, record, and log data for a number of different filter types.

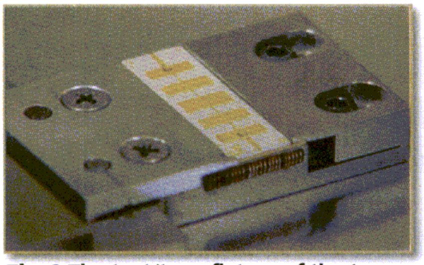

Fig. 3 The test/tune fixture of the tuning station has two positions on a precision slide for either testing or tuning.

Continued from page 103

required hand-staking the inductor at a set temperature, the presence of a highly trained technician, a hand-generated data sheet, and a significant amount of "touch labor." The average tuning time by this method was between one and two hours.

A new automated process was developed to replace the coiled-wire inductor with a planar type of quasi-lumped RF/microwave filter constructed with distributed shunt capacitors, series capacitors, series inductors, and lumped-series capacitors on the input and output ports **(Fig. 1)**. The tuning process involves the removal of material from the shunt-capacitor pads to achieve the desired performance. The advantages of this method over the baseline are quite apparent: no inductor staking is required, a less-skilled operator can perform the tests, the data are computer generated, and minimal touch labor is required.

An automated tuning station was developed following a study of material-removal methods and equipment. Filter performance was determined by a parametric study of the amount of material to be removed for a particular filter configuration. The study included the impact of the removal of substrate material on overall filter performance. The automated tuning station is shown in **Fig. 2**. Its main components include a milling machine (LPKF ProtoMat 91s/Vs), a network analyzer(HP 8720D), computer controller, printer, and custom-designed test/tune fixture.

The test/tune fixture consists of a two-position filter holder mounted on a precision linear slide (back position for testing, front position for tuning) mounted on the front of the milling bed **(Fig. 3)**. In the test position, the controller uses the network analyzer to compare the measured data taken from the filter to a stored data base of expected performance for that filter **(Fig. 4)**. The necessary trimming procedure—unique for each filter—is then determined.

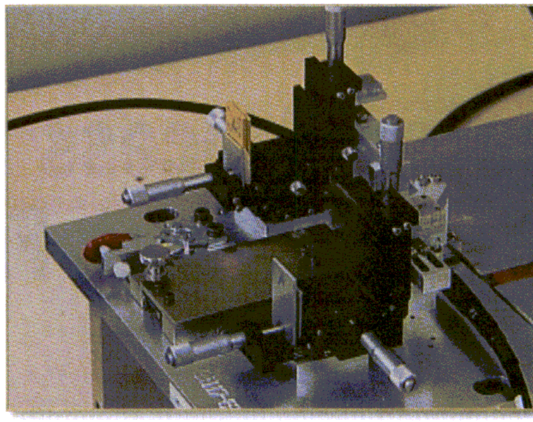

Fig. 4 In the test position shown here, the network analyzer compares data from the filter under test with information stored in a data base.

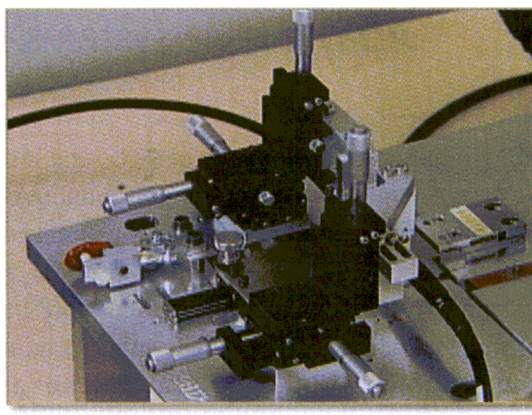

Fig. 5 Once it is determined as to how the filter will be trimmed, the filter is moved to the milling position.

The filter is then moved to the milling position **(Fig. 5)** where the controller directs the milling machine to tune the filter by removing metallization from the circuit **(Fig. 6)**. The depth of the cut is set manually in 1-mil increments using a micrometer adjustment on the milling head. The filter is cycled between the testing and tuning positions until the desired electrical performance is achieved. Upon completion of the tuning cycle, the controller prints out a data sheet for the next level of assembly and stores the information in a data base. Several types of filters can be tuned with this method, including quasi lumped-element, resistively damped, and interdigital types.

The automated process can tune a filter in 10 minutes or less, a significant reduction in tuning time from the baseline process. In addition, the time saved in associated fabrication processes further reduced production time. Eliminating the inductor staking together with shorter times for substrate curing, assembly, and tuning results in a total time savings of 10 hours per filter. It is anticipated that further improvements in analysis software in conjunction with parametric studies can determine the required physical configuration of filters. This will enable the precise etching of a filter, completely eliminating the need for tuning. The tuning process has been applied initially to S- and C-band filters used in the Patriot Advanced Capability 3 (PAC-3) Air Defense System. MRF

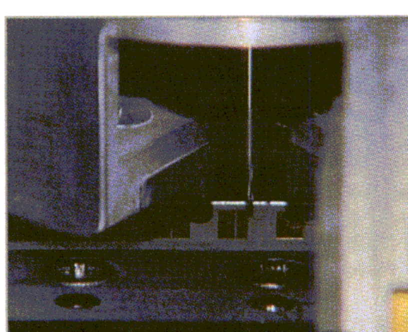

Fig. 6 In the milling position, the milling machine is directed by the controller to tune the filter by removing metallization from the circuit.

ACKNOWLEDGEMENT

This work was performed under an Army Manufacturing Technology Program-funded project entitled "Automated Tuning of Microwave Filters for Master Frequency Generators" by Lockheed Martin Missiles and Fire Control, Chelmsford, MA. The following were instrumental in ensuring the success of the program: Dave Savoia, Steve Rajkowski, Joe Whitney, and Marc Gomes-Casseres.

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Upgraded SPICE Package Soars With New Features

Veteran SPICE users as well as newcomers will appreciate the seamless integration of new features to be found in the latest version of this PC circuit-simulation tool.

ALAN ("PETE") CONRAD
Special Projects Editor

Simulation Program with Integrated Circuit Emphasis (SPICE) has been the tool of choice for designers of analog, digital, and mixed-signal circuits since its introduction by the University of California at Berkley (Berkeley, CA) in 1970. Commercial versions of the software abound with the ICAP/4 program from Intusoft (San Pedro, CA) which offers significant improvements and advancements since 1985. The latest version of ICAP/4 offers improved ease of use and some powerful new functions, including Fast Fourier transform (FFT) and inverse FFT capabilities.

This latest version of Intusoft's ICAP/4 is actually much more than just a SPICE package. It is a suite of programs that allows designers to create a schematic diagram from a library of more than 14,000 parts, and then analyzes and improves performance. Once a circuit is created, the IsPice SPICE analysis software module can be used to perform a frequency-domain or time-domain simulation of performance. ICAP/4 also features an interactive graphical waveform-processing module (IntuScope) which can be used to analyze and display IsPice waveforms and a program simulation manager called SpiceNet **(see figure)**.

New features in ICAP/4 include the ability to write specialized scripts and assign hot keys to eliminate repetitive design tasks. The latest version of the software also adds the capability to perform FFTs (to convert time-domain information to real and imaginary values in the frequency domain), inverse FFTs (to convert real and imaginary values in the frequency domain to the time domain), and wavelet transformations. Other new additions include the ability to write equations in an on-screen calculator window and the ability to construct and alter graphs using the calculator's menu.

By taking advantage of special features in the schematic-diagram menu, operators can interconnect circuit diagrams to create different design configurations, and then simulate each configuration separately. The latest

Continued on page 108

The latest version of the ICAP/4 SPICE circuit simulator offers an improved user interface and a host of new operating functions.

Continued from page 107

version of the program has also simplified tuning and optimization, enabling single and multiple parameter sweeps. Operators can view the results of varying a component value each time that the component is changed. Interactive simulations and parameter extractions can be controlled through more than 100 Interactive Commands Language (ICL) commands and functions. ICL script can also be passed into the simulator.

A new library manager simplifies model archiving. Users can archive ICAP/4 model libraries, compare new models with stored ones, search the model library for duplicate parts, define models symbolically rather than with a net list, and create test drawings for models. The library manager brings up a list of all the models in a library and provides a comparison to archived models.

ICAP/4's user-configurable tool bar provides single-click access to any menu item, including launching a simulation and viewing operating-point data on a schematic diagram. Text or artwork can be placed anywhere on a schematic diagram. Waveform thumbnails can be imported from the IsPice waveform viewer using the probe tool and single clicking on a node or part. A document or image can be embedded or linked anywhere on a schematic diagram. Multiple schematic-layer capability makes it possible to place schematic objects anywhere on a circuit layer.

IsPice4 makes it possible to explore circuit performance by interactively running different analyses and sweeping any circuit variable. With the ability to simulate electrical, data, mechanical, physical, thermal, and other systems, the program is a true interactive native mixed-mode SPICE 3/XSPICE-based simulator that supports mixed analog, digital, and digital-signal-processing (DSP) circuits. With these features, the program can perform a variety of application simulations such as switch-mode power supplies, mixed-signal application-specific integrated circuits (ASICs), RF communication systems, interconnects, control systems, and mixed mechanical/physical systems.

Analysis types include AC, DC, transient, noise, Fourier, distortion, transfer function, and temperature. Monte Carlo analyses includes statistical yield analysis, root-sum-of-squares (RSS) analysis, and worst-case analysis.

The documentation provided with the ICAP/4 program is excellent, with many practical examples. ICAP/4 accepts Berkeley SPICE 2G.6 or 3F.2 syntax and supports SPICE 2 and 3 outputs. **Intusoft, P.O. Box 710, San Pedro, CA 90733-0710; (310) 833-0710, FAX: (310) 833-9658, Internet: www.intusoft.com.** MRF

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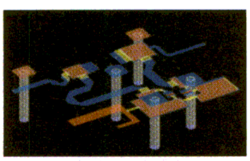
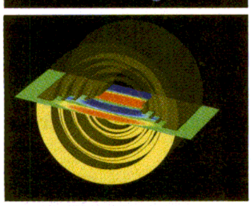
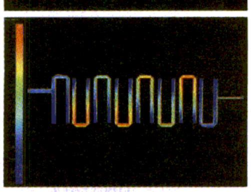
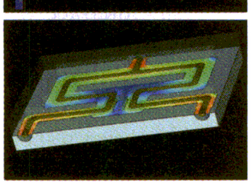

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Program Performs Filter Calculations

Engineers in need of active-, passive-, and digital-filter designs will find this potent program to be an invaluable tool for lowpass, highpass, bandpass, and band-reject filters.

ALAN ("PETE") CONRAD
Special Projects Editor

Filters can be found in practically all electronic circuits and systems. While design engineers have a choice of several fine filter analysis and design programs, one of the better values currently available is the Filter Solutions 8 software from Nuhertz Technologies (Phoenix, AZ). The cost-effective computer-aided-engineering (CAE) program supports the design and analysis of active, passive, and digital filters.

The program **(see figure)** can be used to design a wide range of filter types, including lowpass, highpass, bandpass, and band-reject filters using active, passive, and digital approaches. The program can also be used to create complex filter assemblies, including diplexers and equalizers. The program features all-pass configuration support for the design of delay equalizers, as well as finite-Q analysis for generating single-terminated filter designs or double-terminated designs with equal or unequal load and source resistances. The software can be used in the design of balanced passive filters, passive all-pass filters without coupled coils, coupled-resonator bandpass filters, minimum-inductor zigzag filters, passive amplitude equalizers, and bandpass/band-reject diplexers. Users can export modified passive- and active-filter transfer functions and design active stages around user-supplied capacitors.

The program computes Gaussian, Bessel, Butterworth, Chebyshev Type I, Chebyshev Type II, hourglass, and elliptic filters for lowpass, highpass, bandpass, and band-reject filter classes. S and Z transforms are computed in vector format to easily interface with mathematical analysis programs such as MATLAB. The Filter Solutions program displays transfer functions, pole/zero plots, time responses, frequency responses, and reflection coefficients for all filter designs. Other calculations include Laplace transforms in standard, cascade, and parallel forms with parameter displays of ω0 and Q displays of all cascade and parallel Laplace Transforms for use in active-filter designs.

Once it is given an operator's design specifications, Filter Design 8 will com-

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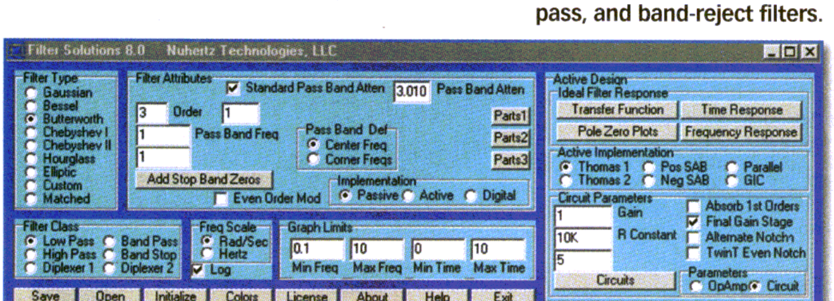
Filter Solutions is a low-cost but powerful filter design and analysis program that can be used to create active, passive, and digital lowpass, highpass, bandpass, and band-reject filters.



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pute up to eight filters internally in its efforts to meet the design specifications. To prevent multiple filters from being displayed, switch settings are provided to narrow the number of displayed filters. Operators can select only first-element shunt filters, first-element series filters, voltage-source filters, or current-source filters. A switch is also provided to display only those filters with minimum inductor count.

Each filter design can have a frequency-domain, reflection, or time-domain analysis performed by selecting the appropriate control on the circuit window (although time-domain analysis may not be available for some diplexers or filters with second-order all-pass stages). Frequency-domain and reflection analyses include magnitude, phase, and group delay. Time-domain analysis includes step, ramp, and impulse responses. Depressing the left mouse key at any location brings up a cursor tracer with the frequency and trace information in the cursor window. These analyses include all user modifications made to the filter. When a filter has been modified by changing, adding, or deleting an element, or if any finite-Q elements are used, an "Ideal" analysis trace appears in dark blue for quick easy comparison purposes.

All synthesized filters are checked for a proper frequency response prior to being displayed. All filters are displayed in easy-to-read graphical formats along with a netlist suitable for further AC or transient analysis. Filters created with the software are unbalanced, although the program's "Help" file contains instructions on conversion from unbalanced to balanced.

Modifying components is simple with Filter Solutions 8. The mouse is used to pass the cursor over the component to be changed, using the left mouse button to click on and change the component's value. It is then a simple matter to generate a frequency-domain, time-domain, or reflection analysis based on the new component values.

Components may be set to specific values, changed by a fixed percentage, or set to the nearest value in a standard parts list, nearest 1-percent industrial standard part, or nearest 5-percent industrial standard part.

The software allows operators to install finite-Q components into their designs so that these realistic filter responses can be compared with a suitable filter design (using components with infinite Q). Filter Solutions is provided with instructive and comprehensive documentation. P&A: $789.00; stock. **Nuhertz Technologies, LLC, 1810 W. Northern Ave., Suite A-9, #175, Phoenix, AZ 85021-5211; (602) 216-2682, FAX: (602) 216-1613, Internet: www.filter-solutions.com.** MRF

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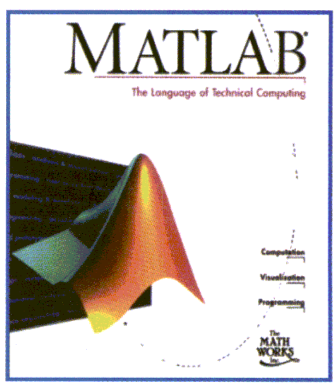
Math Package Boasts Host Of Improvements

Operators will enjoy the improved ease of use and faster access to data files, graphics, and variables with the latest version of this popular mathematical analysis tool.

ALAN ("PETE") CONRAD
Special Projects Editor

Mathematical-processing and analysis programs have long been an essential tool in a high-frequency engineer's design kit. These programs can be used to apply mathematical relationships to the design of oscillators and phase-locked loops (PLLs), as well as the analysis of antenna patterns. The latest version of one of the more popular of these mathematical programs, MATLAB from The MathWorks, Inc. (Natick, MA), has just been upgraded to provide quicker access to models, variables, and the many powerful functions within the software.

MATLAB (**see figure**) is a high-performance technical-computing environment for algorithm development, data analysis, and visualization. Its built-in interfaces make it possible to quickly access and import data from test instruments, stored files, other software programs, and external data bases. In addition, MATLAB can integrate external routines written in C, C++, Fortran, and Java languages.



The latest version of MATLAB features an improved GUI with faster access to the many variables and functions found within the software.

The latest version of MATLAB features a new desktop front end that provides faster access to MATLAB code, variables, data files, graphics, demonstration files, and online help. In addition, multiple new interactive tools provide easy importing, plotting, and exporting of graphics. The latest release also includes major enhancements for mathematical computing, accessing external data and code, and GUI development. Other highlights are a portfolio of tools for managing the MATLAB environment, including the command window, command history window, workspace browser, and array editor.

The program contains new point-and-click tools for interactively editing and annotating graphics, minimizing coding and memorization of graphics commands and attributes, new mathematical computation and algorithm enhancements, an optimized LAPACK library for faster matrix computations, faster FFT-based function performance with the new FFTW library, Qhull-based functions, new differential equation solvers, and more-accurate quadrature algorithms. Other new features include new data statistics and basic fitting tools for

Continued on page 118

Software Speeds Creation Of Circuit Layouts

This easy-to-use schematic-capture and PCB-generation program translates complex sketches to circuit layouts with simple point-and-click control of a computer mouse.

ALAN ("PETE") CONRAD
Special Projects Editor

Circuit layouts were once drawn by hand. The process was slow and tedious, and did not invite revisions to the schematic diagram. Fortunately, in the age of the PC, circuit-layout programs are readily available, although not always at a price as reasonable as the $700 price tag for Circuit Creator Pro (**see figure**) from Advanced Microcomputer Systems (Pompano Beach, FL). The computer-aided-engineering (CAE) software is a complete integrated tool suite with schematic-capture capabilities, a full interactive symbol editor, a printed-circuit-board (PCB)-layout editor, an automatic router algorithm, and Gerber file import and export functions.

The program allows operators to store up to 32 E-sized sheets of logic in a single file using hierarchical designs through a fully interactive GUI. The software supports more than 25,000 parts and symbol combinations with the ability to dynamically mirror and rotate symbols in 16 orientations using a few simple mouse clicks. Parts can be represented with DeMorgan equivalents, true-vector drawn symbols, and bitmaps. A "smart lines" program feature enables real-time auto rerouting while moving. Line styles include straight, angled, and true bezier-curved lines. Other features include complete parts-list, net-list, and

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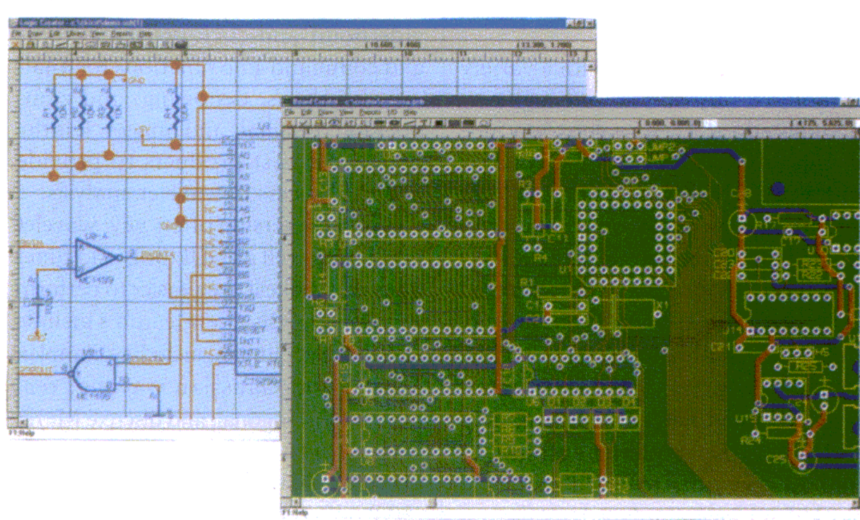

Circuit Creator Pro is a low-cost schematic-capture program that can process PCB layouts as large as 32 × by 32 in. (81.28 × 81.28 cm) with up to 255 layers.

Math Package Boasts Host Of Improvements

Continued from page 115

quick analysis of plotted data, new advanced visualization features including the display of two-dimensional (2D) images, surfaces, and volumes as transparent objects, and an interactive camera toolbar for controlling perspective.

The new GUI enables the naming of Java routines and the use of prebuilt Java objects directly from MATLAB. New serial-port-communication interface are included to communicate with external instruments. An enhanced GUI design tool (GUIDE) is available for developing interfaces and displays. Also, a new add-in module for Microsoft Visual Studio integrates MATLAB code with Visual Studio C/C++ projects, enabling the generation of MATLAB-based projects and C-based MEX files within Visual Studio.

Key features in the new version include numeric computing for quick and accurate results, graphics to visualize and analyze data, an interactive language and programming environment, tools for building custom GUIs, interfaces to external languages such as C, C++, Fortran, and Java, support for importing data from files and external devices and for using low-level file import and export, conversion of MATLAB applications to C and C++ with the Compiler Suite, and access to data bases and additional hardware through add-on products from third-party vendors.

MATLAB is available with a variety of toolboxes for specialized engineering applications. These toolboxes include an improved Signal Processing Toolbox with new GUI. It now contains a filter design and analysis algorithm for designing and analyzing filters. The toolbox also allows users to view only selected areas of analyzed signals for viewing, and a new tool-bar interface for signal manipulation. Simulink® is an interactive tool for modeling, simulating, and analyzing dynamic systems. It enables operators to build graphical block diagrams, simulate dynamic systems, evaluate system performance, and refine designs.

An improved digital-filter-design toolbox provides advanced techniques for designing, simulating, and analyzing digital filters. It extends the capabilities of the Signal Processing Toolbox, adding architectures and design methods for demanding real-time DSP applications. It also provides functions that simplify the design of fixed-point filters and analysis of quantization effects along with an instrument-control toolbox that provides features for communicating with data-acquisition (DAQ) devices and instruments, such as spectrum analyzers, oscilloscopes, and function generators. Support is provided for GPIB and VISA communication protocols.

A DAQ toolbox makes it possible to control and communicate with a variety of external DAQ hardware devices. The toolbox allows operators to configure external hardware, stream live data directly into MATLAB for analysis, and export data from MATLAB to other devices and applications. This toolbox includes support for computer boards devices that support analog inputs, analog outputs, and digital inputs and outputs.

An improved Wavelet toolbox builds on the numeric and visualization capabilities of MATLAB to provide graphical tools and command-line functions for analysis, synthesis, denoising, and compression of signals and images.The toolbox builds on the numeric and visualization capabilities of MATLAB to provide point-and-click graphical tools and command-line functions for analysis, synthesis, denoising, and compression of signals and images. It is the one of the first products to provide practical access to wavelet analysis.

This latest version offers new wavelet families as well as GUI tools and functions that make it even easier to perform wavelet analysis. New features include new wavelet families, including complex Morlet and Gaussian wavelet; real reverse biorthogonal; and discrete Meyer wavelets. **The MathWorks, Inc., 3 Apple Hill Dr., Natick, MA 01760-2098; (508) 647-7000, FAX: (508) 647-7001, Internet: www.mathworks.com.** MRF

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design-verification reports with on-screen interactive error checking.

The software can process PCBs as large as 32 × 32 in. (81.28 × 81.28 cm) with up to 255 layers. A user-selectable cursor layout function supports geometry resolution as fine as 1 mil; drawings taking advantage of this resolution are not limited to the drawing grid, providing designers with a great deal of flexibility. Line widths can be specified from 0.001 to 0.255 in. (0.003 to 0.648 cm) Other features include support for full blind and buried via holes, full surface-mount support, multiple text attributes per circuit board, and the ability to export files to 15 popular CAE programs.

The program's features include the ability to print or display detailed reports for net lists, parts lists, connectivity checks, board summaries of pads used, a listing of line widths, as well as power and ground planes with or without thermal relief. Other capabilities include a built-in print queue for up to 10 masks, user-programmable design-rule checking, net-list import from most schematic-capture programs, and interactive parts placement with "rats nest" prompting for optimal component placement and signal-trace routing.

The software's automatic routing functions include a proprietary artificial-intelligence routing algorithm, routing of two layers at a time with different line widths, protection of networks prerouted by the user, selectable routing parameters for line widths and clearances, and manual or automatic generation of routing schedules.

Circuit Creator Pro runs on IBM PCs and compatible machines with at least 15 Mb of available hard-disk memory, a color VGA monitor, mouse, and the Windows 95, 98, 2000, or Millennium Edition (ME) operating system. The software comes with documentation that helps operators quickly get started to create circuit-layout files. **Advanced Microcomputer Systems, Inc., 1460 SW 3rd St., Pompano Beach, FL 33069; (954) 784-0900, FAX: (954) 784-0904, Internet: www.advancedmsinc.com.** MRF

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frequencies and allocation of four different time slots provides eight different radio-link variations. This avoids interference and improves frequency efficiency and data throughput compared with the point-to-multipoint architecture, according to Bayer.

Each antenna is connected to a T/R module through a waveguide filter designed for high out-of-band rejection and very-low in-band insertion loss. These filters, which generally cost several hundred dollars, cost Radiant less than $2.00 because they are manufactured with pressure die casting and plastic molding, and are integrated into a single cavity. The filter uses an 11-section Chebychev bandpass filter combined with a waffle-iron lowpass filter in a bend waveguide structure.

"The tricky part was in having rotating antennas connect to a single T/R module," says Bayer. "The conventional approach is to use a single T/R module per link. We are now sharing one T/R module between two antennas." The T/R module uses commercially available gallium-arsenide (GaAs) monolithic microwave integrated circuits (MMICs) and a multilayer circuit structure that combines the DC interconnects with the RF circuit. RF channelization and screening of the RF functional blocks, circuit cavities, and integral waveguide-to-microstrip transitions are fabricated as part of the T/R module assembly.

The output-switch matrix of the module can be commanded to select between antennas, as well as either transmit or receive channels with good isolation (greater than 30 dB) and low insertion loss (less than 0.35 dB). Construction of the millimeter-wave module is based on a set of four drums superimposed in the vertical plane with 360-deg. rotation in the horizontal plane, implemented with a rotary waveguide joint connecting the rotating elements of a pair of adjacent drums. The assembly is enclosed within a radome.

The goal of Radiant Networks is to reduce the cost of the ODU enough to make LMDS competitive. With the approach just described, the company claims it has reduced the cost to $1000 per subscriber unit. "We're using off-the-shelf components because they're available," says Bayer. "The residential product will have our own ICs, and will be substantially less expensive."

Virginia Tech (Blacksburg, VA) is arguably one of the most proficient LMDS developers in the world. It is the only university to hold two LMDS licenses, and it has been serving hundreds of "customers" within the university since May 1999. The Blacksburg network supports IP-based services, VoIP, videoconferencing, analog voice, and analog video. It is a point-to-multipoint system based on Harris Clean Burst 1000 (formerly Wavetrace) equipment with a hub located on a dormitory at the school that feeds the remote LMDS connections into the campus network through fiber and Ethernet.

One of the remotes serves the departmental undergraduate and graduate labs and adjacent museum, and the other serves an off-campus administrative office, as well as a student-television learning studio. The office uses the LMDS network for access to data bases and other operational applications. The learning studio produces the student-run campus television station. All digital content downloaded for the broadcasts, including audio, video, text, and weather is transferred over the LMDS network.

A third remote links a local Internet service provider to the campus, providing two T1 lines with enough bandwidth to serve several hundred students. The propagation issues have been dealt with effectively, according to Tom Callahan, LMDS project manager. "It's just an pre-engineering exercise now," says Callahan. "It takes a rainfall rate of 3 in. per hour before the line is dropped. Around here that happens only an hour or less a year and lasts only a minute or two as the storm passes."

For the lack of truly inexpensive millimeter-wave equipment, Dennis Sweeney, a professor at Virginia Tech, is spearheading a project to create a

The concept shows how an LMDS system could be created with simple, millimeter-wave components.

"neighborhood LMDS" system based on components traditionally used for other purposes. As a design goal, Sweeney and other researchers at Virginia Tech set out to create an LMDS transceiver capable of Ethernet speeds with a range of 100 to 300 m with a manufacturing cost of less than $300.

The result is a system based on millimeter-wave devices used in the 24-GHz industrial-scientific-medical (ISM) band for wireless data transmission **(Fig. 2)**. The Gunn-diode-based transceivers are most commonly found on Doppler-triggered door openers and intrusion alarms. The varactor-tuned modules for these applications are available for $50 to $60 in small quantities. The initial system based on these devices has delivered a reliable data rate of 1.5 Mb/s with the potential of 10 Mb/s, according to Sweeney.

The sensor consists of a 5-mW varactor-tuned Gunn-diode oscillator and mixer optimized for direct conversion to baseband. The components are mounted in a small die-cast waveguide, and the antennas are small horns manufactured of metallized plastic. The low-power output of the transceiver necessitated a more distributed approach than the common point-to-multipart architecture where the transceivers act as repeaters.

The system is less sophisticated than commercial products, but the concept shows how an LMDS system could be created with simple millimeter-wave components. A further issue for development is pinpointing a network failure. Sweeney proposes incorporating a simple system monitor based on a priority-interrupt-controller (PIC) processor and analog-to-digital converter (ADC) in each transceiver that checks system functions such as received signal strength, automatic-frequency-control (AFC) voltage, mixer current, as well as power-supply voltage and cabinet temperature. The monitor could be programmed to alert a system administrator if a performance parameter varies from the acceptable range. MRF

Accuracy of crystal-controlled instruments explained

AN INSTRUMENT'S ABILITY to measure or create frequency is only as good as the accuracy of its internal frequency reference. In most cases, it is a crystal oscillator. That oscillator's accuracy is subject to a number of different uncertainties that result in errors in its time base and, therefore, errors in measurement. A seven-page description of the different types of frequency uncertainty in crystal oscillators is provided in "Understanding Frequency Accuracy in Crystal Controlled Oscillators," from the Microwave Measurements Division of Anritsu Corp.

The note is not intended for time-base designs, but rather to explain the various time-base uncertainties and how they can affect a measurement. Engineers understand that the greatest error contributor is temperature variations, and the calculations to determine the amount of error are very straightforward. Nevertheless, the note shows two ways to calculate the worst-case time-base uncertainty depending upon how the temperature stability of the crystal oscillator is specified.

The second-largest contributor to time-base uncertainty is errors with respect to time: short-term stability and long-term aging. Generally, short-term stability is not a significant error contributor because modern circuit design keeps the value in the range of 1 part in 10^{10} for a quality time base. Long-term aging is a somewhat different matter since long-term frequency accuracy cannot be determined independent of time. Since a crystal ages with time and changes the oscillator frequency, the time between calibrations of the oscillator must be known to determine the time-base uncertainty.

Although shock and vibration are likely to be third-order uncertainty effects, the note explains how they affect the total time-base uncertainty. Other subjects that are covered include an overview of crystal-oscillator operation, , and how crystal aging affects time-base uncertainty. The note can be obtained by downloading it from the company's website.

Anritsu Co., Microwave Measurements Div., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; Internet: www.us.anritsu.com.

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The narrowing of the data-sampling window becomes more of a problem with increases in operating frequency.

Take the jitters out of understanding oscillator jitter

MUCH HAS BEEN written about oscillator jitter over the past few years because it plays a key role when reducing errors in digital data of communications. Designers who want to bypass a lot of theory and get some practical design guidance on jitter are well advised to read an eight-page application note entitled "Oscillator Jitter FAQ" from MF Electronics Corp.

As the title implies, the note is written in a question-and-answer format, as used routinely on Internet sites. It starts with the basics, first defining jitter and then looking into its causes, particularly with wireless applications in mind. The illustrations simplify the explanations for some causes of jitter. For example, jitter caused by a logic device's variable triggering threshold is shown in three different colors to illustrate how a signal can be delayed or start early depending on the trigger level of the logic device. Another good multicolor illustration shows how jitter compromises data reliability by narrowing the width of the data-sampling window. If the window becomes too narrow, it will be difficult to determine whether the data signal is a 1 or 0 at sampling time.

The narrowing of the data-sampling window becomes more of a problem with increases in operating frequency. As the note points out, for each doubling of frequency, the maximum window available for sampling is halved.

Other questions and answers in the note deal with matters explaining why the rise time of the data and clock signals are important and why waveform symmetry is important. A slow-rise data signal detracts from the maximum period of full-scale voltage (the time when the data are either at a 1 or a 0). Thus, the signal is increasingly susceptible to reading errors as a result of jitter or other distortions. Waveform symmetry is a critical element because communications circuits use the leading and trailing edges of waveforms to trigger logic events. An ideal clock signal, for example, will have a 50-percent duty cycle and any asymmetry can displace the leading and trailing edges away from the center of the data windows where the logic value of the data is read. The note is available by contacting:

MF Electronics Corp., 10 Commerce Dr., New Rochelle, NY 10801; (914) 712-2200, FAX: (914) 576-6204, e-mail: will@mfelectronics.com

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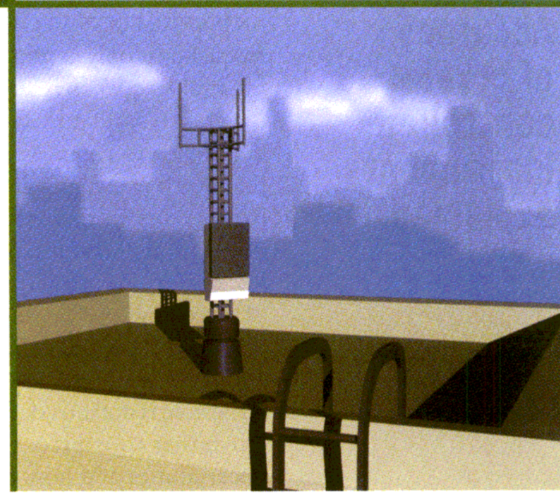

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Sawtek's voltage controlled SAW oscillators deliver the specs your need for low g-sensitivity, very low noise floors and low phase noise. The differential output Emitter Coupled Logic (ECL) clock is perfect for the low jitter requirements of SONET, Ethernet and network servers. Sawtek's new single-ended sine wave oscillator is ideal for broadband applications such as SONET, LMDS/MMDS point-to-point and multi-point microwave systems. When your designs demand vibration immunity and aggressive cost-effectiveness, demand oscillators from Sawtek...they deliver.

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Single-Ended Sine Wave VCSO

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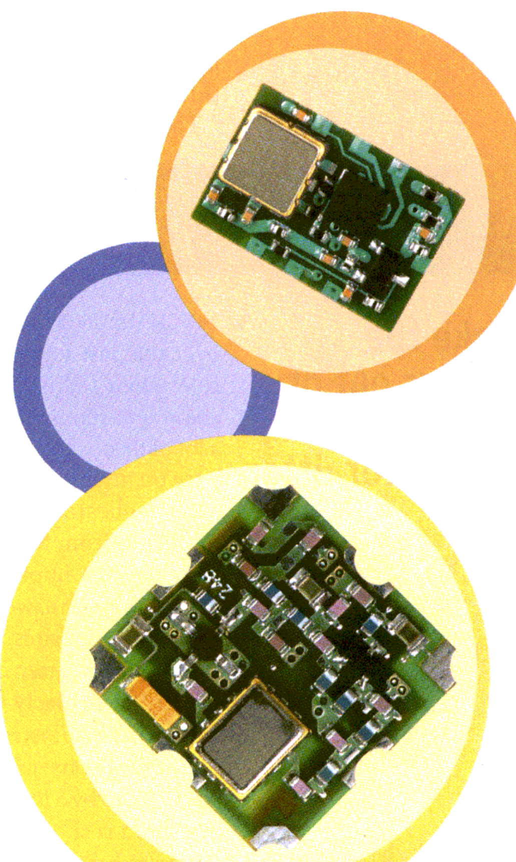
- STW technology offers low phase noise (-120 dBc/Hz to -135 dBc/Hz at 10 kHz, -165 dBc/Hz at 1 MHz) and exceptional high frequency jitter performance (<5 fS RMS)



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cover story

Diminutive Splitter Channels 5 To 1000 MHz

This tiny power splitter delivers full-sized performance for signal-processing applications from 5 to 1000 MHz where PCB area is at a premium.

ENGINEERING STAFF
Mini-Circuits, P.O. Box 350166, Brooklyn, NY 11235; (718) 934-4500, FAX: (718) 332-4661, Internet: www.minicircuits.com.

Power dividers/combiners are the invaluable passive components that allow transmitters (Txs) and receivers (Rxs) to add and subtract signals as necessary. Traditionally, broadband power dividers/combiners operating below 1 GHz have been based on ferrite transformers, in order to convert a low input impedance to the 50-Ω characteristic impedance of an RF system. Due to the inclusion of the transformer, these broadband splitters have been limited to package sizes generally on the order of 0.50 in. (1.27 cm) on a side.

But the model SBTC-2-10 power splitter from Mini-Circuits (Brooklyn, NY) breaks with tradition by squeezing full-scale, 5-to-1000-MHz performance into a compact package measuring only 0.15 × 0.15 × 0.15 in. (0.38 × 0.38 × 0.38 cm)

The model SBTC-2-10 **(Fig. 1)** is a two-way power splitter that also serves as a power combiner. It compares in performance to currently available multi-decade-bandwidth splitters measuring 0.25 × 0.31 in. (0.64 × 0.79 cm) and larger. Traditionally, reductions in size for power splitters have been possible by using external resistors and capacitors,[1] but at a sacrifice in additional parts and lost printed-circuit-board (PCB) space due to the use of the external components. The model SBTC-2-10 requires no external components, making use of high-level integration techniques to pack all necessary

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components within a tiny surface-mount package. Since the SBTC-2-10 splitter is so small, multiple-output splitters (such as four-way and eight-way dividers) can be formed from cascading several SBTC-2-10 units, without sacrificing valuable PCB space.

Basically, a power splitter is formed of an input impedance-matching section, a divider section, a capacitor, and a resistor. In a 50-Ω system, the impedance at the input of the divider is close to 25 Ω. The matching transformer converts this low input impedance to the characteristic 50 Ω of most RF systems at the RF input to provide a good impedance match for minimal signal power loss. Normally, a capacitor (C) is required to match the reactive part of the impedance. The resistor (R) plays a critical role in providing isolation between the two RF output ports.

As seen in **Fig. 2**, a power splitter consists of four components. Traditional construction of the splitter requires a large PCB area [of the order of 0.25 × 0.31 in. (0.64 × 0.79 cm)]. In contrast, the base of the model SBTC-2-10 is constructed with Blue Cell Technology™ which is based on low-temperature-cofired-ceramic (LTCC) fabrication techniques. The LTCC technology is also employed in the fabrication of active multichip modules (MCMs) for applications such as cellular base stations and Bluetooth transceiver modules. The Blue Cell Technology makes it possible to embed the resistor and the capacitor within the power-splitter circuitry, while a ferrite transformer is used to perform the power-splitting and matching function. Connections between components and to the package are formed through the company's proprietary welding process. Electrical contacts are brought to the bottom of the splitter circuit board through via-hole connections. The result is a power splitter/divider capable of operating from 5 to 1000 MHz with low insertion loss and high isolation, and very repeatable performance from unit to unit.

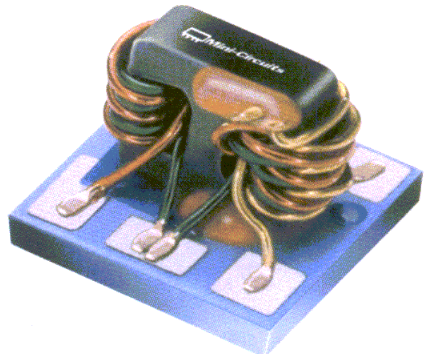

Fig .1 The SBTC-2-10 makes use of a highly integrated manufacturing approach to achieve a 5-to-1000-MHz bandwidth in a tiny package.

Power-divider performance can be specified in terms of several key parameters, such as insertion loss, isolation, power-handling capability, amplitude imbalance, phase imbalance, and voltage standing-wave ratio (VSWR). In a power splitter, a measure of insertion loss is the different between the amplitudes of the input signal and output signals, but also taking into account the theoretical loss associated with splitting a signal. In a two-way power splitter, for example, each output signal is theoretically 3 dB less in amplitude than the input signal. In a four-way splitter, the theoretical power-splitting difference is 6 dB. So, specifications presented for power-splitter insertion loss generally assume the splitting loss,

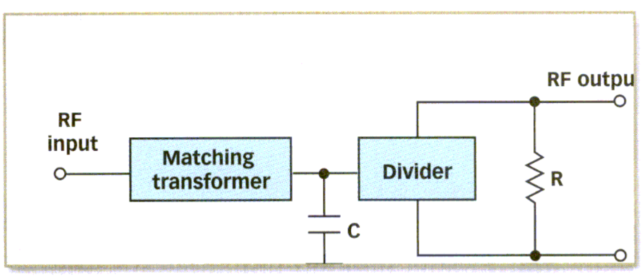

Fig. 2 The SBTC-2-10 consists of four basic components: an input impedance-matching section, a divider section, a capacitor, and a resistor. All are integrated within the package.

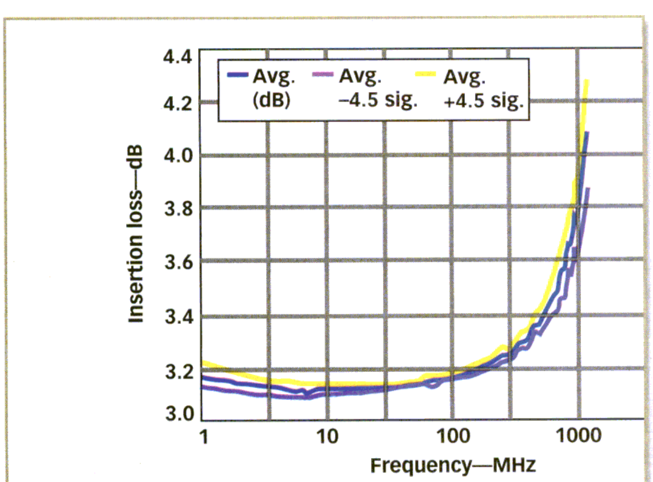

Fig. 3 The "lot" insertion-loss performance of one of the SBTC-2-10's output ports is shown in terms of statistical parameters.

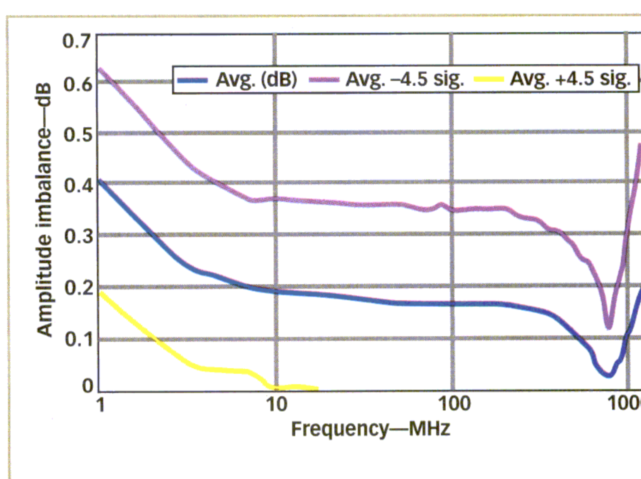

Fig. 4 The measured amplitude unbalance is considerably less than the specified maximum value of 0.6 dB from 0.5 to 1000 MHz.

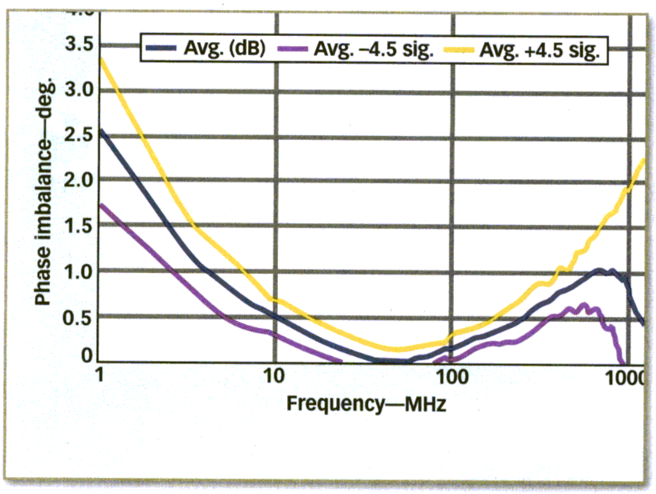

Fig. 5 **The measured phase imbalance compares well with the specified performance.**

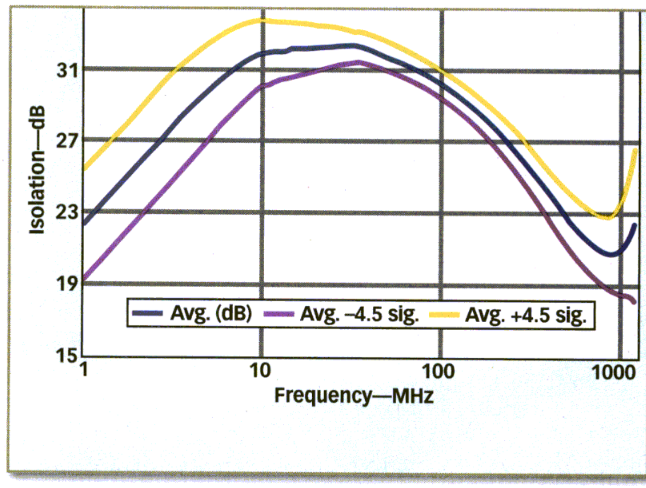

Fig. 6 **Measurements show the isolation between ports to be typically 20 dB through 1000 MHz.**

showing only the insertion loss above whatever signal losses occur due to power division.

Isolation in a power splitter is a measure of the signal crosstalk that occurs between ports or channels. It is defined as the attenuation between a signal at any output port and the level of the signal at another output port, with the input port terminated in 50 Ω. Unwanted signal feedthrough or crosstalk can result in undesirable spurious signal products further along the signal-processing chain in a system. The highest values of isolation are preferred, with values of 20 dB or better generally acceptable for most applications.

The power-handling capability of a splitter/combiner depends upon the use of the component. As a divider, the component can handle higher input-power levels than as a combiner, where the resulting output power will be some combination of the total input-power levels minus the insertion loss. Since a splitter/combiner must dissipate power as heat internally, the input-power specification for the combiner function is derated compared to the specification for use as a power splitter.

Component repeatability is of prime concern for system designers. The compact nature of the SBTC-2-10 design results in very repeatable performance. **Figure 3** shows the insertion-loss performance of the component through three curves. One curve identifies the mean performance of multiple units, while the other two curves show the mean minus a 4.5-Σ value and the mean plus a 4.5-Σ value. The insertion loss above the nominal 3-dB splitting loss is rated as typically 0.3 dB at lower frequencies, typically 0.3 dB at midband, and typically 0.5 dB at the upper frequencies. The maximum insertion loss across the operating band is 1.4 dB.

The compact design of the SBTC-2-10 results in a very small standard deviation (typically 0.02 dB), indicating that variations from unit to unit are almost negligible. The manufacture of these units is also very consistent between individual ports. **Figure 4** shows the amplitude imbalance—the differences in amplitude between the splitter's two output ports. The amplitude imbalance is rated for a maximum of 0.6 dB across the full operating band. Measurements indicate typical amplitude imbalance of only 0.1 dB, with a standard deviation of 0.04 dB.

The phase imbalance is similarly impressive. Rated at a maximum of 5 deg. across the full operating band, and as low as 3 deg. from midband to the lower-frequency limit, measurements show the phase imbalance to be considerably less than the specified level **(Fig. 5)**, with variations between units to be extremely small (a standard deviation of typically 0.1 deg.).

The SBTC-2-10 is rated for isolation of typically 29 dB at the lower frequencies, 25 dB at midband, and typically 21 dB at the upper-frequency limit, with worst-case isolation of 16 dB across the full operating band. Actual measurements show the isolation between ports to be typically 20 dB through 1000 MHz **(Fig. 6)**. This parameter is normally very sensitive to assembly parasitics in other designs and varies from unit to unit. In the SBTC-2-10, the standard deviation for isolation is typically 0.5 dB, which signifies very-low unit-to-unit variations.

The input/output matching of the power splitter is well-controlled, with VSWR performance of typically 1.15:1. The power splitter is designed for applications from 5 to 1000 MHz, but is usable from 1 to 1200 MHz. It can handle input-power levels up to 0.5 W when used as a splitter and input-power levels up to 0.125 W when used as a power combiner.

The SBTC-2-10 power splitter/combiner is available in tape-and-reel format for use on high-volume, automated-assembly production lines. It is rated for operating temperatures from −40 to +85°C. **Mini-Circuits, P.O. Box 350166, Brooklyn, NY 11235; (718) 934-4500, FAX: (718) 332-4661, Internet: www.minicircuits.com.** MRF

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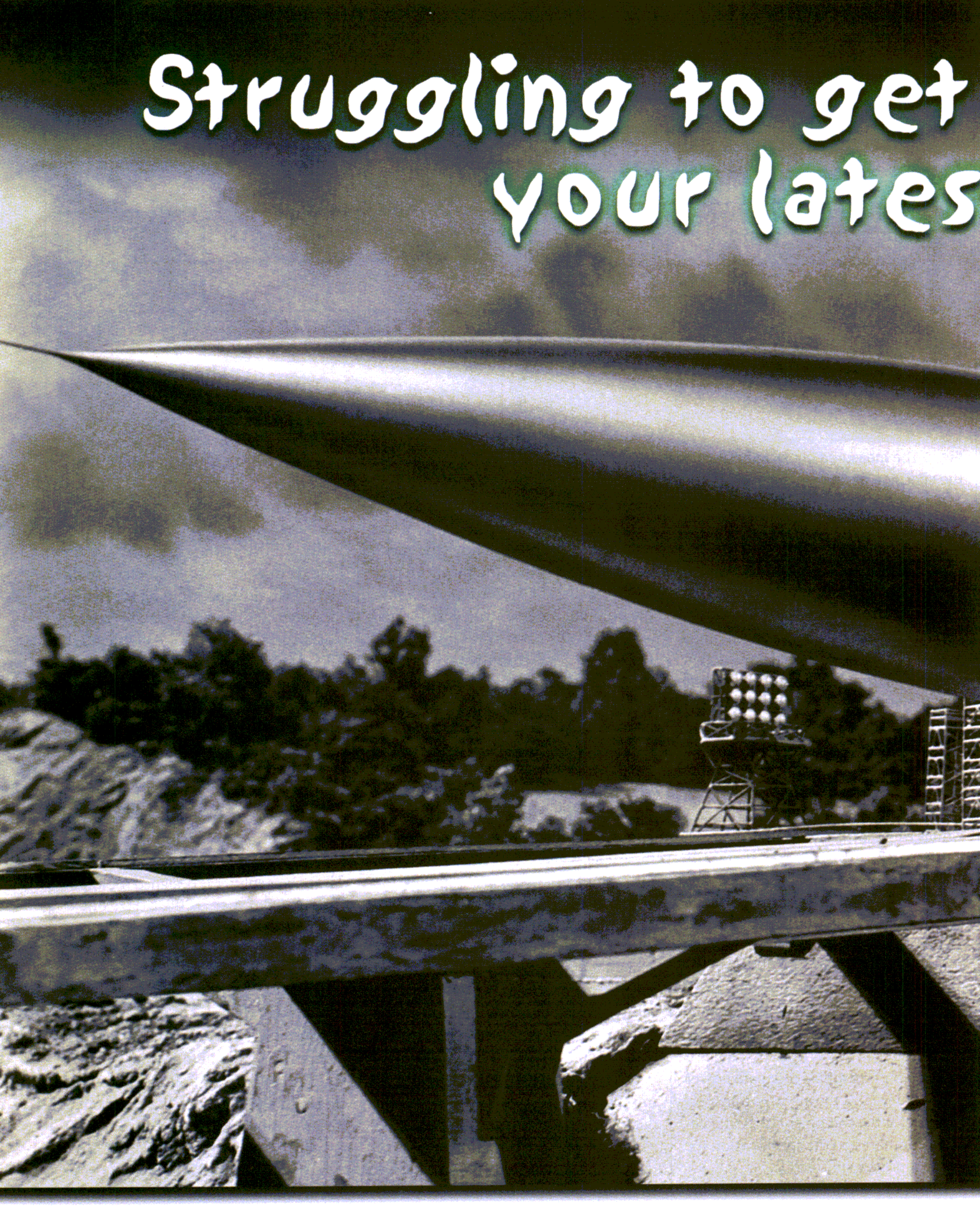
REFERENCE

1. Engineering Staff, Mini-Circuits, "Do-it Yourself Low-Cost Power Splitter," *Microwave Product Digest,* May 2000.



Discover a new planet

Personal Monitor Checks RF Safety Levels

This family of compact RF personal monitors employs a unique triple-sensor design to detect almost every possible signal format from 100 kHz to 100 GHz.

JACK BROWNE
Publisher/Editor

Health and safety issues often impact workers in RF-intensive environments, such as food-processing plants and industrial plants using RF heaters and sealers. The Nardalert XT RF personal monitor from Narda Safety Test Solutions (Hauppauge, NY), however, can be a greatly calming influence for workers in such environments, since the compact monitor is designed to automatically detect RF radiation according to established standards from 100 kHz to 100 GHz. The Nardalert XT RF personal monitors are available for all major worldwide EM field-level standards, including the IEEE C95.1-1999/ANSI C95.1-1992, the German DIN VDE 0848 (Part 2), FCC 1997, the Canadian Safety Code 6 99-EHD-237, and the Japanese RCR-38 standards. The patented triple-sensor design detects electric fields from 100 kHz to 100 GHz regardless of signal format or polarization. A low-frequency, low-impedance surface-area sensor detects the radial fields that are characteristic of low-frequency communications systems. A diode-dipole design complements the low-frequency sensor in the UHF region by detecting vertically polarized electric fields. To extend the frequency coverage, a microwave sensor uses thermocouple detection for operation to approximately 10 GHz, and traveling-wave detection for coverage through 100 GHz.

Users can select an audio alarm, a vibrator alarm, or both. In addition, five high-intensity LEDs show RF levels at levels of 10, 20, 50, 100, and 200 percent of a standard. Either one or both of the two LEDs that indicate the lowest RF levels (10 and 20 percent) can be deactivated to conserve battery power. A built-in data logger automatically records the average field strength (when used in its default mode). The Nardalert XT RF personal monitors measure only 10.5 × 7.6 × 3.5 cm and weigh 157 g; they can be used with a pocket clip or a belt clip. The monitor operates with a single AA battery, with approximately 800-hours operating lifetime when the LEDs and alarms are turned off. The monitors are available in three series for specific standards: the 8860 and 8862 series are available with and without data-logging capability, respectively, while the 8861 series is designed for strong ELF fields. **Narda Safety Test Solutions, an L3 Communications Co., 435 Moreland Rd., Hauppauge, NY 11788; (631) 231-1700, FAX: (631) 231-1711, e-mail: NardaSTS@L-3COM.com, Internet: www.narda-sts.com.**

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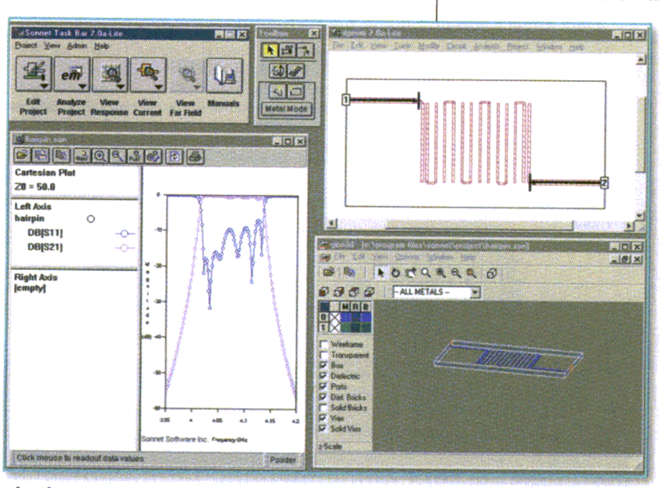
Enhancements Grace Free EM Simulator

The second generation of a free EM-simulation package is an educational tool that will also serve as a design guide for microstrip and stripline circuit analysis.

ALAN ("PETE") CONRAD
Special Projects Editor

Something for nothing usually sounds too good to be true. But in the case of the Sonnet Lite™ 7.0 software from Sonnet Software, Inc., (Liverpool, NY), the something is a powerful high-frequency electromagnetic (EM) simulation tool that can be used for analyzing and modeling microstrip and stripline circuits, while the nothing is the price. The latest version of this free software tool is based on the proven Sonnet em professional suite currently used by many major manufacturers of high-frequency components and systems operating from 1 MHz through 1 THz.

The name "Sonnet Lite" is a relative term, when judging the capabilities of this software tool against the features of the full-scale Sonnet em software suite, which performs EM analysis on planar circuits using method-of-moments (MoM) solutions. This is truly no lightweight package, with the capability of performing EM analysis on three-dimensional (3D) planar circuits using a maximum of two metallization layers and a maximum of four ports.



The latest version of the free Sonnet Lite™ simulation software was used to design and analyze a microwave hairpin filter. Here, the software's multiple windows show the filter's layout and amplitude response as a function of frequency.

Sonnet Lite can be used to analyze planar structures such as microstrip-matching networks, stripline circuits, microstrip or stripline filters with via holes (interlayer or grounding via holes), to characterize mounting pads, to analyze coupled transmission lines, and to evaluate the crosstalk between metal traces on printed-circuit boards (PCBs). As an example, the program was used to develop and plot the simulated performance of a hairpin filter **(see figure)**. The software can also be used to analyze microwave-circuit discontinuities, spiral inductors with bridges, broadside-coupled transmission lines, planar interconnects, and any planar circuit for which circuit theory programs have no models. Essentially, if a structure can be drawn, it can be modeled with Sonnet Lite.

Why give away a powerful modeling tool? The "giveaway" program is part of educational efforts on the part of Sonnet Software founder Jim Rautio to familiarize engineers with the capabilities of EM simulation. High-frequency EM software offers significant capability to the RF, digital, analog,

Continued on page 130

Continued from page 129

or microwave engineers who know how and when to use it. However, in the past, its use was limited only to those who could afford it, and who had opportunities to learn to use it. The giveaway program, which began approximately two years ago, has progressed to this second, upgraded version of Sonnet Lite, with a host of improvements compared to the first version, and reinforcing Sonnet's desire to bring EM simulation to the masses.

Sonnet Lite provides a level of capability that may be sufficient for a large number of engineering users. There is so much power on this disk that many users may never need another planar EM-field solver. When they do need more capabilities, however, a low-cost upgrade is available that doubles the amount of memory usage allowed, provides the capability to import and export DXF files, and enables single-parameter EM-based performance optimization.

Sonnet Lite can be used for visualization of current density and circuit responses. It can also be used to analyze package effects and the influence of a shielding enclosure. Circuit-response data can be exported in standard file formats for use with simulation tools from other software suppliers. The software also provides the capability to perform Simulation-Program-with-Integrated-Circuit-Emphasis (SPICE) model extractions.

Although Sonnet Lite is free upon request, it should be made clear that this is not a full-functioning software tool, especially compared to the capabilities of the Sonnet em software suite. Sonnet Lite has limitations on the size of the circuits that it can analyze. The initial memory limit upon installation is 1 Mb, but this limit can be increased to 16 Mb simply by registering the program.

Sonnet Lite is supplied on a compact-disc-read-only memory (CD-ROM) and runs on any IBM or compatible personal-computer (PC) system with a Pentium processor, the Windows 95, 98, 2000, NT, or Millennium Edition operating systems, a minimum of 32 Mb of random-access memory (RAM) and 55 Mb of available hard-disk space. P&A: free and $495.00 (upgrade that doubles the memory allowance for stored designs, provides DXF file import and export capabilities, and provides the capability to perform single-parameter EM-based optimizations). **Sonnet Software, Inc., 1020 Seventh North St., Suite 210, Liverpool, NY 13088; (877) 776-6638, (315) 453-3096, FAX: (315) 451-1694, Internet: www.sonnet usa.usa.** MRF

Enter No. 54 at www.mwrf.com

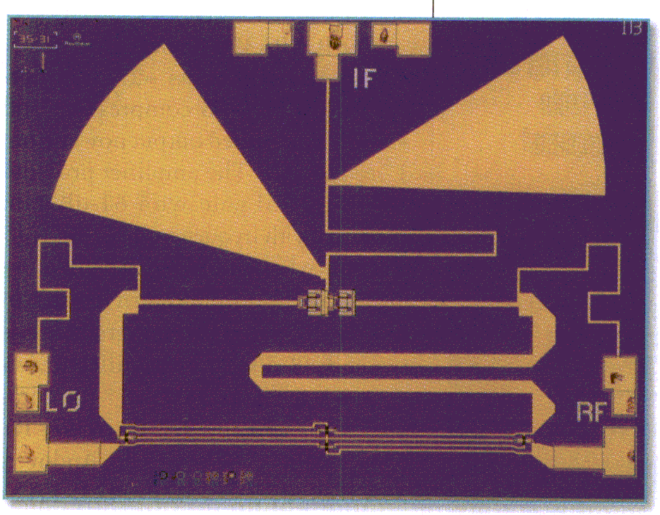
Radio Chip Sets Power Millimeter-Wave Systems

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 gallium-arsenide (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 61.4-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 215-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.

Continued on page 132

Continued from page 131

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 220-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 of 18 to 22 GHz, 27 to 30 GHz, and 37 to 40 GHz, respectively. All three are three-stage designs and fabricated with a 0.15-mm gate-length power GaAs PHEMT process. The RMPA19000 measures 4.45 3 3.50 mm and delivers +28-dBm output power at 1-dB compression and +29-dBm saturated output power. The OIP3 is +37 dBm. The amplifier provides 26-dB typical gain with 61-dB gain variation with frequency. The power-added efficiency (PAE) is 15 percent, the output return loss is typically 10 dB, and the input return loss is typically 8 dB. The amplifier draws 660-mA drain current at 1-dB compression and +5 VDC.

The RMPA29000 delivers +30-dBm output power at 1-dB compression and +30.5-dBm saturated output power from 27 to 30 GHz. The output IP3 is +37 dBm. The amplifier provides 23-dB typical gain with 61-dB gain variation with frequency. The PAE is 25 percent (when measured at 1-dB compression), the output return loss is typically 10 dB, and the input return loss is typically 8 dB. The amplifier draws 850-mA drain current at 1-dB compression and +5 VDC.

The RMPA39000 measures 4.28 × 3.19 mm and delivers +27-dBm output power at 1-dB compression and +28-dBm saturated output power from 37 to 40 GHz. The amplifier provides 15-dB typical gain with 61-dB gain variation with frequency. The PAE is 15 percent (when measured at 1-dB compression), the output return loss is typically 7 dB, and the input return loss is typically 8 dB. The amplifier draws 750-mA drain current at 1-dB compression and +5 VDC. **Raytheon RF Components, 362 Lowell St., Andover, MA 01810; (978) 470-9421, FAX: (978) 470-9201, Internet: www.Raytheon.com/micro.** MRF

Enter No. 55 at www.mwrf.com

Fast Synthesizer Races From 4.5 To 6010 MHz

This measurement-grade microwave frequency synthesizer combines fast-switching speed, low phase noise, and minimal spurious content in a reliable, modular architecture.

JACK BROWNE
Publisher/Editor

Frequency switching speed can translate into profitability for firms involved in large-volume production testing. And in those production test lines, the FastSource 1000 frequency synthesizer from Aeroflex Comstron (Plainview, NY) will never be the bottleneck: the agile source operates from 4.5 to 6010 MHz with less than 100-μs switching speed to within 1 radian of the final phase/frequency.

Compare the switching speed of the FastSource 1200 to that of a conventional microwave synthesizer that requires approximately 20 ms to shift from one frequency to the next. But the FastSource 1200 is also a clean source, with maximum spurious levels of −65 dBc from 4.5 to 2000 MHz, −60 dBc from 2000 to 4000 MHz, and −55 dBc from 4000 to 6010 MHz. The phase noise is typically −110 dBc/Hz offset 1 kHz from the carrier, −125 dBc/Hz offset 10 kHz from the carrier, −125 dBc/Hz offset 100 kHz from the carrier, and less than −130 dBc/Hz offset 1 MHz from the carrier. The noise floor reaches as low as −147 dBc/Hz at a 10-MHz offset ranging from 1000 to 2000 MHz. Harmonic signal levels are a maximum of −25 dBc from 4.5 to 6010 MHz, while subharmonic content is typically −60 dBc and a maximum of −50 dBc.

The FastSource 1200 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 frequency resolution is the result of a multiloop synthesizer architecture using a low-noise output-loop VCO with a frequency range of 1 to 2 GHz and a scaler/multiplier.

For ATE applications, the FastSource 1200 frequency synthesizer offers parallel BCD and GPIB control ports. The synthesizer is locked to an internal 10-MHz OCXO, but can also be used with an external 10-MHz reference oscillator.

The FastSource 1200 synthesizer is constructed of RF modules linked to a common motherboard for ease of maintenance. The modules and circuit boards use SMT components for optimum and reliable performance. The rack-mount instrument measures 19.0 × 3.50 × 22.28 in. (48.26 × 8.89 × 56.59 cm) and is designed for use at operating temperatures from +10 to +45°C. **Aeroflex Comstron, 35 South Service Rd., Plainview, NY 11803; (516) 694-6700, FAX: (516) 694-2562, Internet: www.aeroflex.com.** MRF

Enter No. 57 at www.mwrf.com

Surge Protector Suits 250-VAC Networks

THE MODEL DSI 50E is a heavy-duty AC power-surge protector designed for wireless base stations and cellular sites. The unit protects one phase with a patented technology, combining three layers of metal-oxide varistors (MOVs) and thermal fuses. It is available for 110-to-120- and 220-to-250-VAC networks. The surge protector has a power-dissipation capability of 140 kA. It is UL-1449 second edition listed and Consumer Services Association (CSA) approved. It is equipped with visual indicators and remote signaling. The unit is DIN Rail mountable.

CITEL, Inc., 1111 Parkcentre Blvd., Suite 340, Miami, FL 33169; (305) 621-0022, FAX: (305) 621-0766, e-mail: citel4u@ix.netcom.com, Internet: www.citelprotection.com.

● **Enter No. 62 at www.mwrf.com**

Amplifiers Offer +9-dBm Output Power

TWO MILLIMETER-WAVE, HIGH-POWER monolithic-microwave-integrated-circuit (MMIC) amplifiers cover the 24-to-40-GHz frequency band with output power up to +9 dBm. The FMM5703X is a high-gain, wideband amplifier for operation in the 24-to-32-GHz frequency range, while the FMM5704X is a high-gain, wideband amplifier for operation in the 36-to-40-GHz frequency range. The units offer a +9-dBm output, 18-dB power gain, and input and output at 50 Ω. The devices are designed for point-to-point or point-to-multipoint radio-link and local-multipoint-distribution-system (LMDS) applications. The units are suitable for satellite and radio-link applications where low noise and high dynamic range are required.

Fujitsu Compound Semiconductor, Inc., 2355 Zanker Rd., San Jose, CA 95131; (408) 232-9500, (408) 232-9600, FAX: (408) 428-9111, e-mail: sales@fcsi.fujitsu.com, Internet: www.fcsi.fujitsu.com.

● **Enter No. 63 at www.mwrf.com**

VCO Provides +3-dBm Output Power

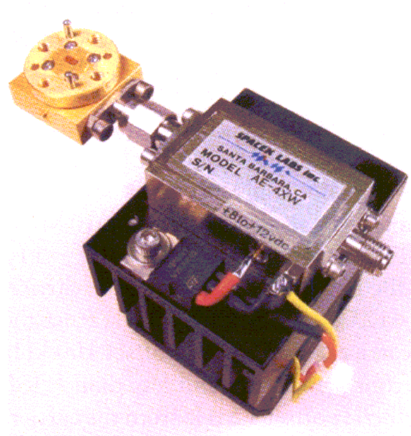
THE MN-SERIES VOLTAGE-CONTROLLED-OSCILLATOR (VCO) model MN3300MS provides tuning of 3.3 GHz with phase noise of −100 dBc at 10-kHz offset and −120 dBc at 100-kHz offset. The VCO provides output power of +3 dBm with harmonic rejection of −20 dBc. Tuning voltage is +0.5 to +4.5 VDC with an input of +5.0 VDC. The MN series features an industry-standard surface-mount-technology (SMT) package that is fully compatible with pick-and-place and reflow processing.

MODCO, Inc., 808 Packer Way, Sparks, NV 89431; (775) 331-2442, FAX: (775) 331-6266, Internet: www.modcoinc.com.

● **Enter No. 64 at www.mwrf.com**

Multiplier Spans 60 to 90 GHz

THE MODEL AE-4XW is an active X4 multiplier covering the entire E-band (60 to 90 GHz). Input power is +10 to +15 dBm at 15.0 to 22.5 GHz. Output power is +4 dBm typical with a minimum output power of +2 dBm. Narrowband units can also achieve +10-dBm output power.



Spacek Labs, Inc., 212 E. Gutierrez St., Santa Barbara, CA 93101; (805) 564-4404, FAX: (805) 966-3249, e-mail: spacek@silcom.com, Internet: www.spaceklabs.com.

● **Enter No. 65 at www.mwrf.com**

VCO Boasts +9.5-dBm Power Output

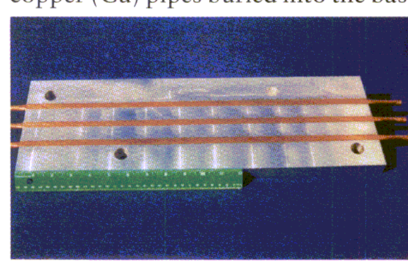
THE MODEL ROS-400 is a broadband +12-VDC voltage-controlled oscillator (VCO) that features a current of 20 mA maximum. The unit provides 200-to-380-MHz typical near-octave-band tuning and a phase noise of −100-dBc/Hz single sideband (SSB) at 10-kHz offset. Power output is +9.5 dBm and harmonic suppression is −24 dBc. Measuring 0.50 × 0.50 × 0.18 in. (1.27 × 1.27 × 0.46 cm), applications include test instruments such as signal generators. P&A: $14.95 (5 to 49 qty.).

Mini-Circuits, P.O. Box 350166, Brooklyn, NY 11235; (718) 934-4500, FAX: (718) 332-4661, e-mail: sales@minicircuits.com, Internet: www.minicircuits.com.

● **Enter No. 66 at www.mwrf.com**

Cold Plates Cool Power Transistors

PP-6.5X20X1-S IS A three-pass cold plate and PP-5x12x0.5-A is a four-pass cold plate for cooling high-power-device laser diodes and power transistors. Known as the Piped series, the units have copper (Cu) pipes buried into the base plate. Contact surfaces are milled to extreme flat and smooth for better heat transfer. Thermal resistance of 0.001°C/W or less can be achieved. Other high-cooling power designs are available. P&A: PP-6.5x20x1-S ($250.00 each) and PP-5x12x0.5-A ($40.00 each).



ACK Technology, Inc., 7372 Walnut Ave., Unit S, Buena Park, CA 90620; (714) 739-5797, FAX: (714) 739-5898, e-mail: ackinc@aol.com, Internet: http://www.ack-technology.com.

● **Enter No. 67 at www.mwrf.com**

Antenna Spans 15.7 To 16.2 GHz

THE MODEL 9968-800 is a waveguide flat-plate-array antenna that uses two box-horn arrays. Frequency range is 15.7 to 16.2 GHz, gain is 34 dBi minimum, and beamwidth is 4.2-deg. azimuth with 2.1-deg. elevation. Polarization is linear and horizontal with a broadside beam angle. With a VSWR of 1.5:1, the unit is housed in a 11.5 × 22.0 × 2.0-in. (29.2 × 55.9 × 5.1-cm) package.

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

● **Enter No. 68 at www.mwrf.com**

Oscillators Cover −20 To +75°C

THE SURFACE-MOUNT TCVCXO-1707 series oscillators cover the 12.6-to-19.8-MHz frequency range. Stability is ±2.5 PPM over an operating temperature range of −20 to +75°C. Pullability is 5 to 15 PPM with a control voltage of +1.5 VDC ±1 VDC. Supply voltage is +3.3 VDC with a maximum current of 2 mA at +3 VDC. The units are housed in a 5.0 × 3.2-mm package. P&A: $6.00 to $7.00 each (10,000 qty.); delivery to 16 wks.

ILSI America, 5458 Louie Lane, Reno, NV 89511; (775) 851-8880, FAX: (775) 851-8882, e-mail: e-mail@ilsiamerica.com, Internet: www.ilsiamerica.com.

● **Enter No. 69 at www.mwrf.com**

Capacitors Work From −25 To +85°C

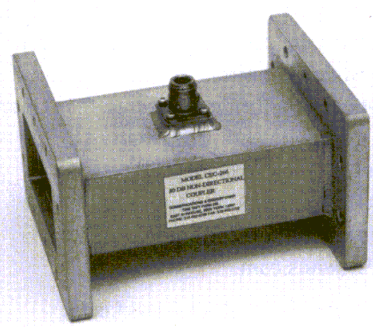
THE 9344 SERIES of single-turn ceramic chip-trimmer capacitors are designed for high-volume commercial applications. The five surface-mount trimmers range from 1.7 to 3.0 pF and 5.5 to 30 pF. The working voltage is +100 VDC and operating temperature range is −25 to +85°C. The units are packaged as 1000 pieces on a 7.00-in. (17.78-cm) reel. P&A: $0.24 each (5000-piece qty.); 6 to 8 wks.

Johanson, Rockaway Valley Rd., Boonton, NJ 07005; (973) 334-2676, FAX: (973) 334-2954, e-mail: mcsales@johansonmfg.com, Internet: www.johansonmfg.com.

● **Enter No. 70 at www.mwrf.com**

Coupler Monitors MMDS Power Flow

THE MODEL CEC-266 waveguide coupler inserts into the multichannel-multi-point-distribution-service (MMDS) waveguide transmission line and mounts a coaxial probe for monitoring power levels and other test purposes. Coupling is nondirectional and is 30 dB



±0.5 dB and ranges from 2500 to 2700 MHz. With a type-N female probe connector, the waveguide body is 6 in. (15.24 cm) long with CPR340 flanges on each end. The unit weighs 1.75 lbs. P&A: $295.00 each; delivery to 10 days.

Communications & Energy Corp., Inc., 7395 Taft Park Dr., East Syracuse, NY 13057; (800) 882-1587, (315) 452-0709, FAX: (315) 452-0732.

● **Enter No. 71 at www.mwrf.com**

Inductors Target 7 To 500 MHz

MODELS CF453232 AND CF322522 are surface-mount-device (SMD)-molded wire-wound ferrite-chip inductors for low-to-mid-frequency signal devices such

as computers and communications products. Spanning 7 to 500 MHz, the CF453232 has an inductance range of 0.1 to 1000 μH. The CF322522 features an inductance range of 0.12 to 220 μH. The units are available on tape and reel. P&A: $0.10 ea. in qty.; delivery to 8 wks.

Contact Frontier Electronics, 685 E. Cochran Ave., Simi Valley, CA 93065; (805) 522-9998, FAX: (805) 522-9989, Internet: www.frontierusa.com.

● **Enter No. 72 at www.mwrf.com**

Capacitors Range 3.9 pF To 2.2 μF

THE CHV SERIES OF high-voltage multi-layer-ceramic-chip (MLCC) capacitors features chips in Electronic Industries Alliance (EIA) sizes of 1206, 1210, 1812, 2220, and 2225 in voltages up to 56 kVDC. COG (NPO) and X7R dielectric are also available. The MLCC capacitors are provided in voltages within the ranges of +500 VDC, as well as 1, 2, 3, and 5 kVDC. Capacitance range is 3.9 pF to 2.2 μF. Operating temperature is −55 to +125°C, with temperature coefficient of capacitance (TCC) of ±15 percent/°C for X7R dielectric, and 0 ±30 PPM/°C for COG dielectric. Tape-and-reel packaging is available. P&A: $0.09 to $1.95 each (in production quantities); stock to 10 wks.

Cal-Chip Electronics, Inc., 59 Steamwhistle Dr., Ivyland, PA 18970; (800) 915-9576, FAX: (215) 942-6400, Internet: www.calchip.com.

● **Enter No. 73 at www.mwrf.com**

Filters Feature −1-dB Insertion Loss

THE MODELS S556-5000-14, S556-5000-15, AND S556-5000-30 are surface-mount-technology (SMT) Home Phoneline Networking Alliance (HomePNA) bandpass filters that were designed to meet all electrical standards of Broadcom's iLine10™ (BCM4210 and BCM4100) series of home-networking chip sets. The filters include a transformer and a common-mode choke to ensure high-speed data integrity on existing, non-dedicated phone lines. Insertion loss is −1 dB; average return loss is better than −12 dB; and attenuation is −60 dB at 1.1 MHz, −35 at 22 MHz, and −60 dB at 54 MHz. Minimum inter-winding breakdown voltage is +1500 VRMS with high common-to-differential-mode rejection of −40 dB. Turns ratio is 0.667:1 for transmit and 2:1 for receive. P&A: S556-5000-14 ($2.00), S556-5000-15 ($2.25), and S556-5000-30 ($2.35) (10,000 qty.); stock to 6 wks.

Bel Fuse, Inc., 206 Van Vorst St., Jersey City, NJ 07302; (800) BEL-FUSE, FAX: (201) 432-9542, e-mail: belfuse@belfuse.com, Internet: www.belfuse.com.

● Enter No. 74 at www.mwrf.com

Filters Offer 6-MHz Passband Bandwidth

MODELS CEC-1838(6)-2266.5N AND CEC-1838(6)-2270.5N are bandpass filters that are constructed of welded WR430 aluminum (Al) waveguide. The F_0 frequencies range from 2266.5 to 2270.5 MHz and passband bandwidth is 6 MHz. Insertion loss is 1 dB, though it is 1.25 dB at the band edges. Rejection is 15 dB at ±6 MHz from F_0 while return loss is 18 dB. Connectors are 50 Ω, type N. P&A: $975.00 ea.; delivery to 30 days.

Communications & Energy Corp., 7395 Taft Park Dr., East Syracuse, NY 13057; (800) 882-1587, (315) 452-0709, FAX: (315) 452-0732.

● Enter No. 75 at www.mwrf.com

Receiver Measures FHSS CDMA Coverage

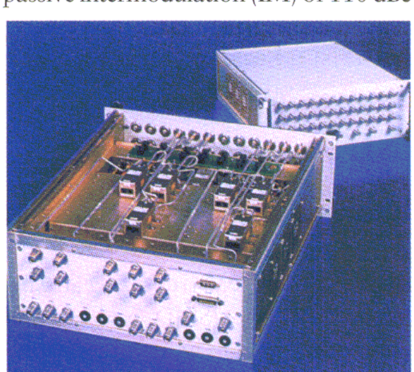
CRICKET™ IS A handheld, wideband, 2.4-GHz receiver (Rx) designed for sweeping and optimizing wireless local-area networks (WLANs). The instrument measures coverage of frequency-hopping, spread-spectrum (FHSS) code-division-multiple-access (CDMA) networks operating on the IEEE 802.11 standard. This enables the user to measure and determine the access-point (AP) packet-error rate (PER) and received-signal-strength-indicator (RSSI) levels that aid in locating hub and APs throughout a building. Cricket demodulates FHSS signals and is compatible with IEEE 802.11. The unit also measures narrowband energy and displays other sources of interference such as microwave ovens and direct-sequence, spread-spectrum (DSSS) signals. The unit includes a built-in display, keypad, and two removable battery packs.

Berkeley Varitronics Systems, Inc., Liberty Corporate Park, 255 Liberty St., Metuchen, NJ 08840; (732) 548-3737, FAX: (732) 548-3404, e-mail: info@bvsystems.com, Internet: http://www.bvsystems.com.

● Enter No. 76 at www.mwrf.com

System Tests WCDMA Base Stations

THE RF TEST Interface System was developed to support the RF testing of wide-band-code-division-multiple-access (WCDMA) base stations. The high-power segment of the system is designed to meet passive intermodulation (IM) of 110 dBc at 2 to 20 W. With a frequency range of 1.5 to 2.7 GHz and an RF power capability of up to 100 W, the system routes and conditions RF signals from the inputs and outputs of the device under test (DUT) to the test equipment, enabling test automation. All of the switchable components have internal CANbus controllers, reducing the internal control lines to only two lines. An internal translator offers an alternative control through standard general-purpose-interface-bus (GPIB) interfaces.

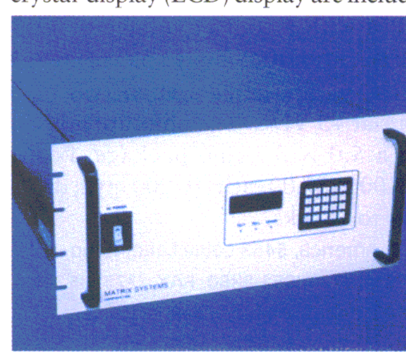


Dow-Key Microwave Corp., 4822 McGrath St., Ventura, CA 93003-7718; (805) 650-0260, FAX: (805) 650-1734, Internet: www.dowkey.com.

● Enter No. 77 at www.mwrf.com

Matrix Targets DC To 120 MHz

THE NONBLOCKING, FULL-FANOUT model 12055 8 × 8 video matrix operates from DC to 120 MHz. Featuring RS-232C and IEEE-488 interfaces, crosspoint verification, and unity gain, the matrix has the capacity to recall up to 40 configurations. Front-panel keypad control and liquid-crystal-display (LCD) display are included. Typical applications include switching red-green-blue (RGB) video from any of eight workstations up to eight combinations of monitors and printers. The rack-mount unit is housed in a 5.00 × 19.00 × 25.00-in. (12.70 × 48.26 × 63.50-cm) package.



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. 78 at www.mwrf.com

Epoxy Cures At Room Temperature

MASTER BOND SUPREME 33 is a high-temperature-resistant epoxy that is curable at room temperature. The epoxy is resistant to long exposures of temperatures up to 425°F. It has high bond strength to metals, glass, ceramics, wood, vulcanized rubber, and most plastics. It is suitable for bonding dissimilar substrates that are exposed to thermal cycling. It can be used in applications that are subject to heavy mechanical vibration, impact, and shock.

Master Bond, Inc., 154 Hobart St., Hackensack, NJ 07601; (201) 343-8983, FAX: (201) 343-2132, Internet: www.Masterbond.com.

● **Enter No. 79 at www.mwrf.com**

Matrix Handles 50 W CW

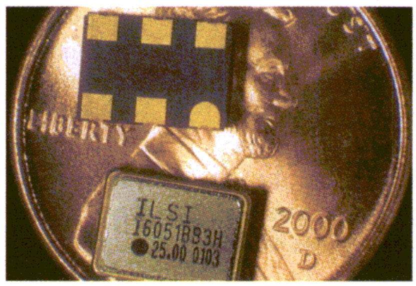
THE P/N 666305 is a 6 × 4 matrix that is capable of handling 50 W continuous wave (CW) from 0.1 to 18 GHz. The unit features a front-panel light-emitting-display (LED) configuration. Control options include direct-keyboard/video-display connect or remote IEEE-488, RS-232, or transmission-control-protocol/Internet-protocol (TCP/IP) connect.

Electronics Development Corp., 9055 F Guilford Rd., Columbia, MD 21046; (410) 312-6650, Internet: www.elecdev.com.

● **Enter No. 80 at www.mwrf.com**

Oscillator Boasts ±50-PPM Stability

THE SMD-1605 SERIES of oscillators covers a frequency range of 1 to 66 MHz with a frequency and temperature stability of



±50 PPM maximum over a temperature range of 0 to +70°C. Two ranges of pullability are ±50 PPM with a control voltage of +1.65 VDC ± 1.5 VDC and a supply voltage of +3.3 VDC. The other range is ±100 PPM with a control voltage of +2.5 VDC ±2 VDC and a supply voltage of +5.0 VDC. The oscillator is housed in a 5.0 × 7.0 × 1.8-mm package. P&A: $2.50 each (10,000 qty.); delivery to 6 wks.

ILSI America, 5458 Louie Lane, Reno, NV 89511; (888) 355-4574, (775) 851-8880, FAX: (775) 851-8882, e-mail: e-mail@ilsi-america.com, Internet: www.ilsiamerica.com.

● **Enter No. 81 at www.mwrf.com**

Mixers Target Millimeter-Wave Spectrum Analysis

A LINE OF harmonic mixers is for use with spectrum analyzers to achieve millimeter-wave spectrum analysis. Mixers are available for waveguide bands from 18 to 325 GHz. Local-oscillator (LO)/intermediate-frequency (IF) diplexers are available for most modern spectrum analyzers. Measured conversion-loss data are supplied with the emulation of most spectrum analyzers for WR-42 through WR-10.

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. 82 at www.mwrf.com**

Data Loggers

MONITORING SOLUTIONS ARE the subject of a 15-page brochure. Temperature and humidity data loggers, remote monitoring systems, temperature and humidity indicators, temperature-chart recorders, pressure-chart recorders, moisture indicators, and universal input recorders are offered. Specifications such as temperature range; frequency range, accuracy, and resolution; and impulse range, accuracy, and resolution are included.

Dickson; (800) 323-2448, Internet: www.dicksonweb.com.

● **Enter No. 83 at www.mwrf.com**

Circular Connectors

A 120-PAGE catalog covers two series of quick connect-disconnect circular connector products. The B-series for mechanical keying includes plugs; bridge plugs; receptacles; fixed couplers; printed-circuit-board (PCB) receptacles; sealed-panel mounted connectors; multicontact inserts; coaxial and triaxial cables; collets; and solder, crimp, and printed-circuit contacts. The S-series for hermaphroditic keying includes vacuum-sealed receptacles; couplers; plug/receptacle combinations; single-contact inserts; coaxial, multiaxial and triaxial cables; as well as mixed and multicontact inserts. Assembly instructions are included. Sections on military standards, test data, and cables are included.

LEMO USA; (800) 444-5366, (707) 578-8811, FAX: (707) 578-0869, e-mail: info@lemousa.com, Internet: www.lemousa.com.

● **Enter No. 84 at www.mwrf.com**

Power Supplies

A 46-PAGE catalog offers several series of power supplies. Ultraminiature modular switching supplies, micro-miniature modular switching supplies, ultra-miniature open-frame switching supplies, and U-bracket-style switching supplies are offered. Enclosed switching supplies, DIN rail-mount switching supplies, external and wall-mount power adapters, low-cost and wide-input-range DC-to-DC converters, and high-power half-brick DC-to-DC converters are also covered.

Astrodyne; (800) 823-8082, (508) 823-8080, FAX: (508) 823-8181, Internet: www.astrodyne.com.

● **Enter No. 85 at www.mwrf.com**

Data-Mate Connectors

INTERCONNECTS ARE FEATURED in a 15-page brochure. Data-mate connectors, high-current cable connectors, insulated hexagonal and circular spacers, surface-mount test sockets, and jumper sockets are presented. Specifications such as material, style, thread, body, and length are presented.

Harwin, Inc.; (812) 285-0055, FAX: (812) 285-0056, e-mail: mis@harwin.com, Internet: www.harwin.com.

● **Enter No. 86 at www.mwrf.com**

Auto-Zero Amplifiers

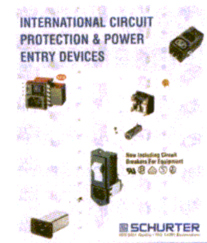
A 56-PAGE magazine offers application notes focusing on analog applications. Subjects include fundamentals of digital-signal-processing (DSP)-based controls for AC machines, adaptively canceling server fan noise, fan-speed-control techniques in personal computers (PCs), measuring small voltages amid large common modes, as well as auto-zero amplifiers. Other articles cover advances in video encoders, selecting an analog front end for imaging applications, and curing comparator instability with hysteresis. A section that contains author information, as well as a feedback questionnaire,is presented.

Analog Devices; (800) 262-5643, (781) 329-4700, FAX: (781) 326-8703, Internet: www.analog.com.

● **Enter No. 87 at www.mwrf.com**

Circuit Protection

A CATALOG FEATURES circuit protection and power-entry devices. Shuttered outlets, live contacts, rewirable cord connectors, resettable fuses, and gold (Au)-plated fuses are offered. Power dissipation charts for power-entry modules and fuseholders are also included.



Schurter, Inc.; (707) 778-6311, FAX: (707) 778-6401, e-mail: info@schurterinc.com, Internet: www.schurterinc.com.

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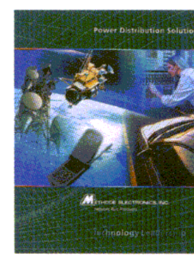
Bus-Bar Systems

A 20-PAGE guide describes the benefits of using laminated bus-bar systems as opposed to conventional wiring harnesses. Electrical performance, space savings, reduced cost, and increased quality are discussed. Design formulas and information on insulation materials are included.



Network Bus Products; (847) 577-9545, FAX: (847) 577-9689, Internet:www.methode.com.

● **Enter No. 89 at www.mwrf.com**

Air Filters

A SERIES OF custom air-filter product technical bulletins is suitable for original-equipment-manufacturer (OEM) designers to use when considering thermal-management options in electronics and industrial equipment. The five-bulletin series features air-filter models used in air cooling of electronics applications such as dual electromagnetic-interference (EMI) honeycomb, polyfold, quadrafoam, and unifoam. Information on airflow resistance, dust arrestance, EMI shielding protection, and low-profile frame options is included.

Universal Air Filter Co.; (800) 541-3478, FAX: (618) 271-8808, Internet: www.uaf.com.

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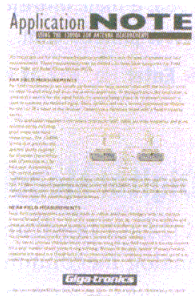
Antenna Measurements


Application NOTE

Giga-tronics

AN APPLICATION NOTE entitled "Using the 12000A for Antenna Measurements" was designed to be used with the 12000A 20-GHz microwave synthesizer. The note describes and diagrams techniques and equipment requirements for far- and near-field measurements. A tutorial on radar cross-section measurement is provided for designers who need to determine reflection characteristics.

Giga-tronics, Inc.; (925) 328-4650, FAX: (925) 328-4700, e-mail: info@ gigatronics.com, Internet: www.gigatronics.com/pdf/antenna_appnote.pdf.

● **Enter No. 91 at www.mwrf.com**

Pump Lasers

A DATA SHEET describes custom-laser solutions, including a company's modular design approach and range of capabilities. Mode-locked picosecond and long-pulse Nd: YAG lasers, chirped-pulse amplification systems, Nd: Glass macropulse systems, and pump lasers are featured. A discussion of the company's design team and quality statements is included.

Continuum; (408) 727-3240, FAX: (408) 727-3550, e-mail: continuum@ceoi.com, Internet: www.continuumlasers.com.

● **Enter No. 92 at www.mwrf.com**

Directional Couplers

TEST EQUIPMENT AND accessories are examined in a 208-page catalog. Adapters, cables, connectors, amplifiers, attenuators, detectors, directional couplers and bridges, filters and limiters, impedance test accessories, mixers, network-analyzer accessories and calibration kits, as well as power dividers are specified. Splitters, power sensors, spectrum-analyzer accessories, switches, switch matrices, terminations, and waveguide accessories are included. A section on new products is also offered.

Agilent Technologies; (800) 452-4844, Internet: www.agilent.com/find/accessories.

● **Enter No. 93 at www.mwrf.com**

Interfaces/Interconnects

THE FULL-LINE catalog (F-201) focuses on high-speed and high-density interfaces. Micro board-to-board, power-to-board, card-to-board, and integrated-circuit (IC)-to-board interconnects are included.

Samtec, Inc.; (800) SAMTEC-9, (812) 944-6733, FAX: (812) 948-5047, e-mail: info@samtec.com, Internet: www.samtec.com.

● **Enter No. 94 at www.mwrf.com**

Coaxial Connectors

A 12-PAGE brochure discusses the SCX series of ultraminiature coaxial connectors. Cable-type connectors, bulkhead connectors, printed-circuit-board (PCB) connectors, surface-mount connectors, and blind-mate connectors are listed. Complete specifications are provided.

Sabritec; (949) 250-1244, FAX: (949) 250-1009, Internet: www.sabritec.com.

● **Enter No. 95 at www.mwrf.com**

Test Probes

CATALOG 119 OFFERS electronic and industrial components. Test probes and microcontrollers are presented, along with services such as ProductFind™, which aids in the location of hard-to-find products. A software tool that helps customers manage stockroom inventory to prevent stock-outs is also discussed. The catalog features tab dividers for quick reference.

Newark Electronics; (800) 4-NEWARK, Internet: www.newark.com.

● **Enter No. 96 at www.mwrf.com**

Production Tools

A 356-PAGE catalog focuses on laboratory equipment and accessories. Production tools, rules and gauges, soldering and desoldering equipment, adapters, inspection systems, electrical meters, cleanroom supplies, and test instruments are specified. Pliers and cutters; copper (Cu) voice, video, and data tools; torque and measuring tools; wrenches and ratchets; knives
and blades; tweezers, inserters and extractors; as well as adhesives are featured.

Techni-Tool; (800) 832-4866, (610) 941-2400, FAX: (800) 854-8665, (610) 828-5623, e-mail: sales@techni-tool.com, Internet: www.techni-tool.com.

● **Enter No. 97 at www.mwrf.com**

Logic Analyzers

AN 18-PAGE catalog presents pulse generators, logic analyzers, plotters, meters, RF signal generators, inductance-capacitance-resistance (LCR) analyzers, spectrum analyzers, precision sources, and oscilloscopes. Frequency counters, RF measurement equipment, impedance analyzers, network analyzers, power supplies, audio analyzers, semiconductors, signal generators, and data-acquisition (DAQ) equipment are included.

Test Equipment Connection Corp.; (800) 615-8378, (407) 804-1299, FAX: (800) 819-8378, (407) 804-1277, Internet: www.TestEquipmentConnection.com.

● **Enter No. 98 at www.mwrf.com**

Panel Meters

ELECTRONICS COMPONENTS ARE specified in a 450-page product catalog. Semiconductors, optics, light-emitting displays (LEDs), panel meters, wire, cable assemblies, connectors, sockets, terminals, oscillators, and resonators are covered. Inductors, transformers, power supplies, switches, relays, circuit breakers, fuses, batteries, as well as heat sinks, tools, and test equipment are offered. A product and suppliers index is provided.

Mouser Electronics; (800) 346-6873, e-mail: sales@mouser.com, Internet: www.mouser.com

● **Enter No. 99 at www.mwrf.com**

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Microwave Synthesizers

A DATA SHEET and a brochure discuss a 20-GHz microwave synthesizer. The data sheet covers product specifications, including frequency ranges, options, accessories, modulation parameters, and frequency modes. The synthesizer's digital architecture, frequency-switching speed, frequency ramp-sweep technique, and modulation capabilities, as well as power and reliability figures are presented in the brochure.

Giga-tronics, Inc.; (925) 328-4650, FAX: (925) 328-4700, e-mail: info@gigatronics.com, Internet: www.gigatronics.com.

Enter No. 100 at www.mwrf.com

Test Equipment

TEST EQUIPMENT IS the subject of a 54-page product catalog. New equipment offerings include oscilloscopes, arbitrary function generators, probes, DC power supplies, waveform generators, data-acquisition (DAQ) equipment, pulse generators, spectrum and network analyzers, as well as cable. Reconditioned equipment offerings feature power supplies, spectrum analyzers above and below 1 GHz, RF measurement equipment, RF signal sources, signal generators, counters, logic analyzers, plotters, oscilloscopes, along with meters.

TestEquity, Inc.; (800) 417-3457, FAX: (800) 272-4FAX, Internet: www.testequity.com.

Enter No. 101 at www.mwrf.com

ICs/Transformers

A 192-PAGE catalog features products suitable for original-equipment-manufacturer (OEM) applications. Integrated circuits (ICs), transformers, computer cables, tools, motherboards, switch boxes, connectors, converters, power supplies, hubs, light-emitting displays (LEDs), and soldering equipment are offered. Module mounting boards, adapters, printed-circuit-board (PCB) connectors, batteries, as well as relay sockets are also available.

Jameco Electronics; (800) 831-4242, (650) 592-8097, FAX: (800) 237-6948, (650) 592-2503, e-mail: info@jameco.com, Internet: www.jameco.com.

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Digital Megohmmeters

A 12-PAGE brochure highlights digital and analog megohmmeters. The brochure provides information on multiple-voltage insulation, resistance, and continuity meters that combine test voltages from +50, +100, +250, +500, and +1000 VDC, and provides insulation measurements to 20,000 Ω depending on model. Specifications are included.

AEMC Instruments; (800) 343-1391, (508) 698-2115, FAX: (508) 698-2118, Internet: www.aemc.com.

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Wideband Coverage

RF, MICROWAVE, AND millimeter-wave components and subsystems for IMT-2000 and Universal Mobile Telecommunications System (UMTS), local multipoint-distribution system (LMDS), point-to-point, and point-to-multipoint applications are featured in a brochure. Transceivers for digital radio systems, low-noise amplifiers (LNAs), RF front-end units, filters, and up/downconverters are discussed.

Nextec Microwave & RF, Inc.; (408) 727-1189, FAX: (408) 727-5915, e-mail: info@nextec-rf.com, Internet; www.nextec-rf.com.

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Optical Connectors

FIBER-OPTIC COMPONENTS are the subject of a 44-page catalog. Optical connectors, ferrules, high-speed switches, variable attenuators, mass-production polishers, as well as cleaning and curing machines are specified. Product descriptions are included.

Seiko Instruments USA, Inc.; (310) 517-7770, FAX: (310) 517-7792, Internet: www.seikofiber.com.

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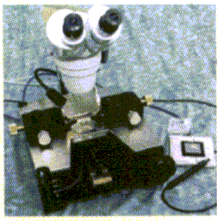

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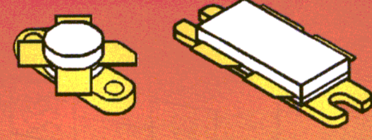

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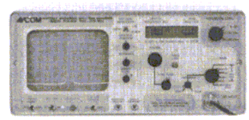
AVCOM PSA-86A Portable 6 GHz Spectrum Analyzer



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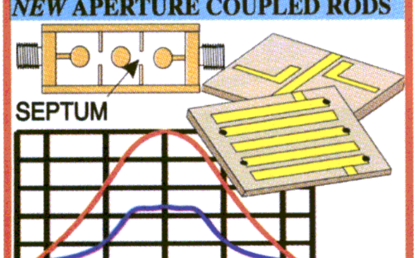

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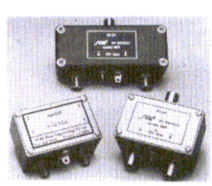

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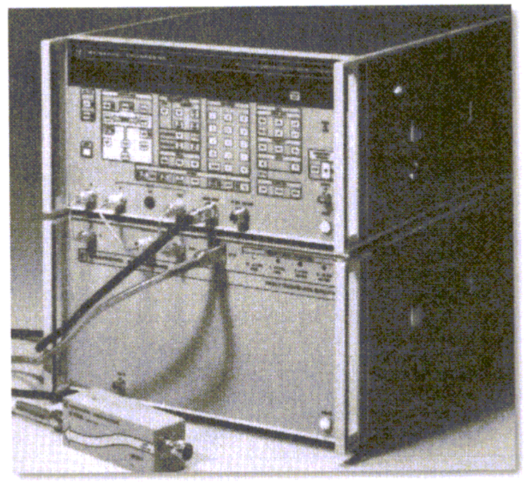

MORE THAN 19 YEARS AGO, the VM-24 calibration system from Weinschel Engineering (Gaithersburg, MD) broke new ground in functional integration for test equipment. The system, which foreshadowed modern communications testers, featured a power meter, frequency counter, signal generator, and modulation meters within a common housing.

next month

Microwaves & RF July Editorial Preview

Issue Theme: Test & Measurement

News

Test-equipment sales are clear indicators of the high-frequency economy. How are these firms responding to this downturn in the economy and what does this mean for research on next-generation test solutions? Don't miss this staff-written report on the state of the health of the test-equipment sector of this industry, and how these manufacturers are taking steps to prepare for ever-more-challenging economic conditions.

Design

July's Design Feature section leads off with a review of broadband channel emulators for mobile communications, examining the hardware and software architectures of different approaches. An author from Florida investigates a low-cost alternative to YIG-based oscillators, while an author from Poland provides an investigation of electronically tuned oscillators, explaining how to measure phase and spurious noise.

Product Technology

The July Product Technology section will offer the first look at a low-cost GPS Rx on a chip designed for embedded applications. Additional product features will highlight the latest product advances from the MTT-S, including a new line of high-power discrete transistors, a 100-W WCDMA PA, and a connector system with interchangeable transition pins.

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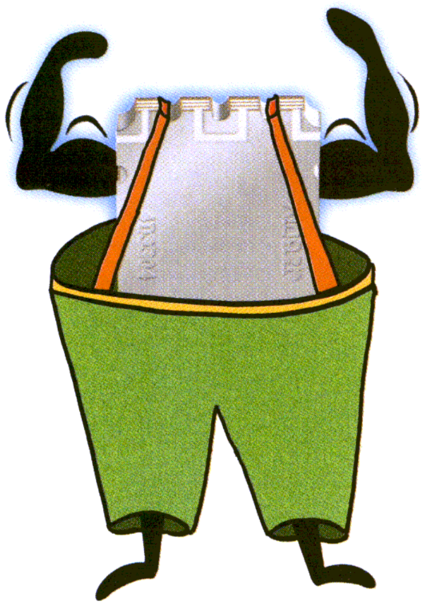
Introducing Anaren's lean, mean, splitting machine.



Xinger® Our new Xinger® three-way power divider provides greater performance in a casing that's less than half the size of the competition's.

Packed into Anaren's tiny 0.65" x 0.48" component is the industry's first true, three-way power divider. That means no more clunky configurations. No more wasted space. No more wasted power.

One input. Three outputs. With each signal inherently the same length for a maximum insertion loss of just 0.3dB with a VSWR of 1.35:1 on the input, and 1.50:1 on the outputs. The perfect complement to any 3G application, this five-component Xinger family covers a host of frequency ranges for D-AMPS, GSM, PHS, PDC, DCS, WCDMA, and UMTS receiver or transmitter applications.

And while we've trimmed down the size with Anaren's patented stripline technology, we've beefed up performance for a maximum amplitude balance of ± 0.2dB and an isolation of >20dB.

And it's *all* backed by Anaren's exclusive B-There™ service commitment — 1-800 ordering, instant quotes on *all* standard products, on-time delivery, and *real* engineering assistance. Plus, free samples in 24 hours for qualified prototype work. And don't forget our 100% On-Spec™ performance guarantee!

Xinger three-way power dividers — exclusively from Anaren.

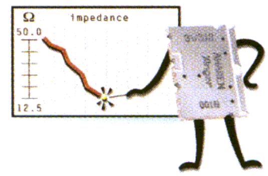
Questions? Contact Anaren at 3waydivider@anaren.com

800-544-2414 > www.anaren.com
In Europe, call 44-2392-232392
Visa/MasterCard accepted (except in Europe)

ISO 9001 certified

Anaren®
What'll we think of next?™

Raise performance by lowering impedance.

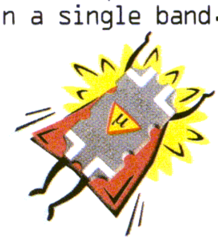


This low impedance Xinger® balun brings impedance down from 50 to 12.5 ohms for greater bandwidth and flatness — in a tiny 0.75" x 0.55" x 0.07" footprint.

> D-AMPS, GSM, PHS, PDC, DCS, WCDMA, and UMTS applications
> Maintains a 180 degree balanced signal
> 15dB minimum return loss; 0.3dB maximum insertion loss
> Amplitude balance of ± 0.2dB
> And our B-There™ service commitment and 100% On-Spec™ performance guarantee!

Anaren®
What'll we think of next?™

Able to leap 5 to 6GHz in a single band.

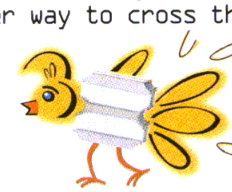


At a mere 0.40" x 0.20" x 0.07", the 1M803 surface mount 90 degree 3dB hybrid coupler is our smallest Xinger® yet!

> U-NII and HiperLAN applications
> Frequency range of 5 to 6GHz
> Maximum average output of 20 watts
> Minimum isolation of 20dB; maximum insertion loss of 0.25dB
> Phase balance of ± 3 degrees; minimum return loss of 20dB
> And our B-There™ service commitment and 100% On-Spec™ performance guarantee!

Anaren®
What'll we think of next?™

An infinitely smarter and safer way to cross the road.



How do you get to the other side? Cross any RF and DC line combination with the 0.20" x 0.20" surface mounted Xinger® Crossover.

> NMT, GSM, UMTS, MMDS and HiperLAN applications
> Frequency range of 0 to 6GHz
> RF-DC and RF-RF components available
> 20dB minimum return loss; 0.10dB maximum insertion loss
> RF-RF version maintains an isolation higher than 25dB
> And our B-There™ service commitment and 100% On-Spec™ performance guarantee!

Anaren®
What'll we think of next?™