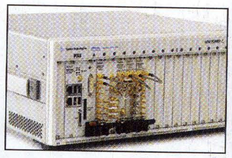
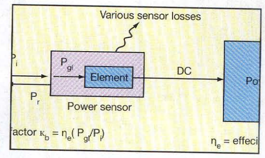
NSIDE TRACK with
MINI-CIRCUITS'
HARVEY KAYLIE:
URVIVING SANDY p28

MEASURING ADVANCES IN RF/MW TEST EQUIPMENT p37



GAUGE THE IMPACT OF TEST UNCERTAINTY p50



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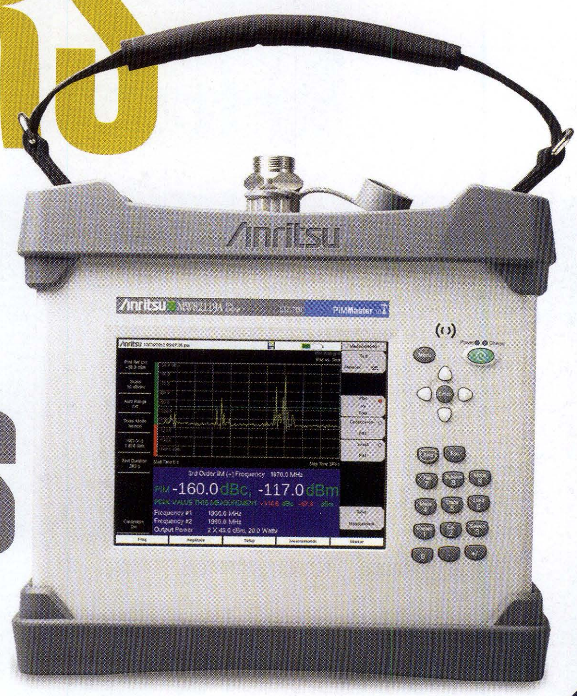

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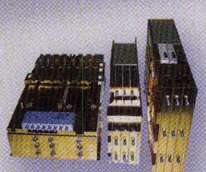
SWITCH MATRICES

Solid State Switch Matrices & Switching Networks to 40GHz

- Amplifiers
- Attenuators - Variable
- DLVA & ERDLVA & SDLVA's
- DTO's
- Filters
- Form, Fit & Function Products
- Hybrids, Dividers & Couplers
- IFM's & Frequency Discriminators
- Integrated MIC/MMIC Modules
- I/Q Vector Modulators
- Limiters & Detectors
- Log Amplifiers
- Pulse & Bi-Phase Modulators
- Phase Shifters
- Rack & Chassis Mount Products
- Receiver Front Ends
- Single Sideband Modulators
- SMT & QFN Products
- Solid-State Switches
- Switch Matrices
- Switch Filter Banks
- Threshold Detectors
- USB Products



- SWITCH MATRICES & SWITCHING NETWORKS
- HANDOVER TEST SYSTEMS
- RF SWITCH ASSEMBLIES
- PROGRAMMABLE ATTENUATOR ASSEMBLIES
- BLOCKING & NON-BLOCKING
- FAN-IN & FAN-OUT CONFIGURATIONS
- BIDIRECTIONAL
- RS-232, RS422/485, PECL, ETHERNET, USB, TOUCH SCREEN & OTHER CONTROL SYSTEMS AVAILABLE
- OTHER INTEGRATED FUNCTIONS AVAILABLE: PHASE SHIFTING, PULSE MODULATION, DETECTION, ATTENUATION, RF FILTERING, ETC.
- LINUX OR WINDOWS OPERATING SYSTEMS, MODULAR DESIGNS, PLUG & PLAY, REMOVABLE COMPACT FLASH WITH BOOT AND OPERATING SOFTWARE
- CUSTOM DESIGNS AVAILABLE TO SUIT YOUR APPLICATION NEEDS

PMI STANDARD SWITCH MATRICES

Model Number	Frequency Range (GHz)	Number Of Inputs To Outputs	Insertion Loss (dB)	Isolation (dB)	OIP3 (dB)	Switching Speed (nSec)	VSWR	Max. Input Power (dBm, CW)
SM-20M3G-4X4	0.02 - 3.0	4 / 4	10	60	45	100	2.0:1	20
SM-20M3G-8X8	0.02 - 3.0	8 / 8	14	60	45	100	2.0:1	20
SM-20M3G-16X16	0.02 - 3.0	16 / 16	16	60	45	100	2.0:1	20
SM-20M3G-32X32	0.02 - 3.0	32 / 32	19	60	45	100	2.0:1	20
SM-2G18G-4X4	2.0 - 18.0	4 / 4	14	60	45	100	2.0:1	20
SM-2G18G-8X8	2.0 - 18.0	8 / 8	16	60	45	100	2.0:1	20
SM-2G18G-16X16	2.0 - 18.0	16 / 16	19	60	45	100	2.0:1	20
SM-2G18G-32X32	2.0 - 18.0	32 / 32	23	60	45	100	2.0:1	20
SM-18G40G-4X4	18.0 - 40.0	4 / 4	16	60	45	100	2.0:1	20
SM-18G40G-8X8	18.0 - 40.0	8 / 8	18	60	45	100	2.0:1	20
SM-18G40G-16X16	18.0 - 40.0	16 / 16	22	60	45	100	2.0:1	20
SM-18G40G-32X32	18.0 - 40.0	32 / 32	25	60	45	100	2.0:1	20

PMI

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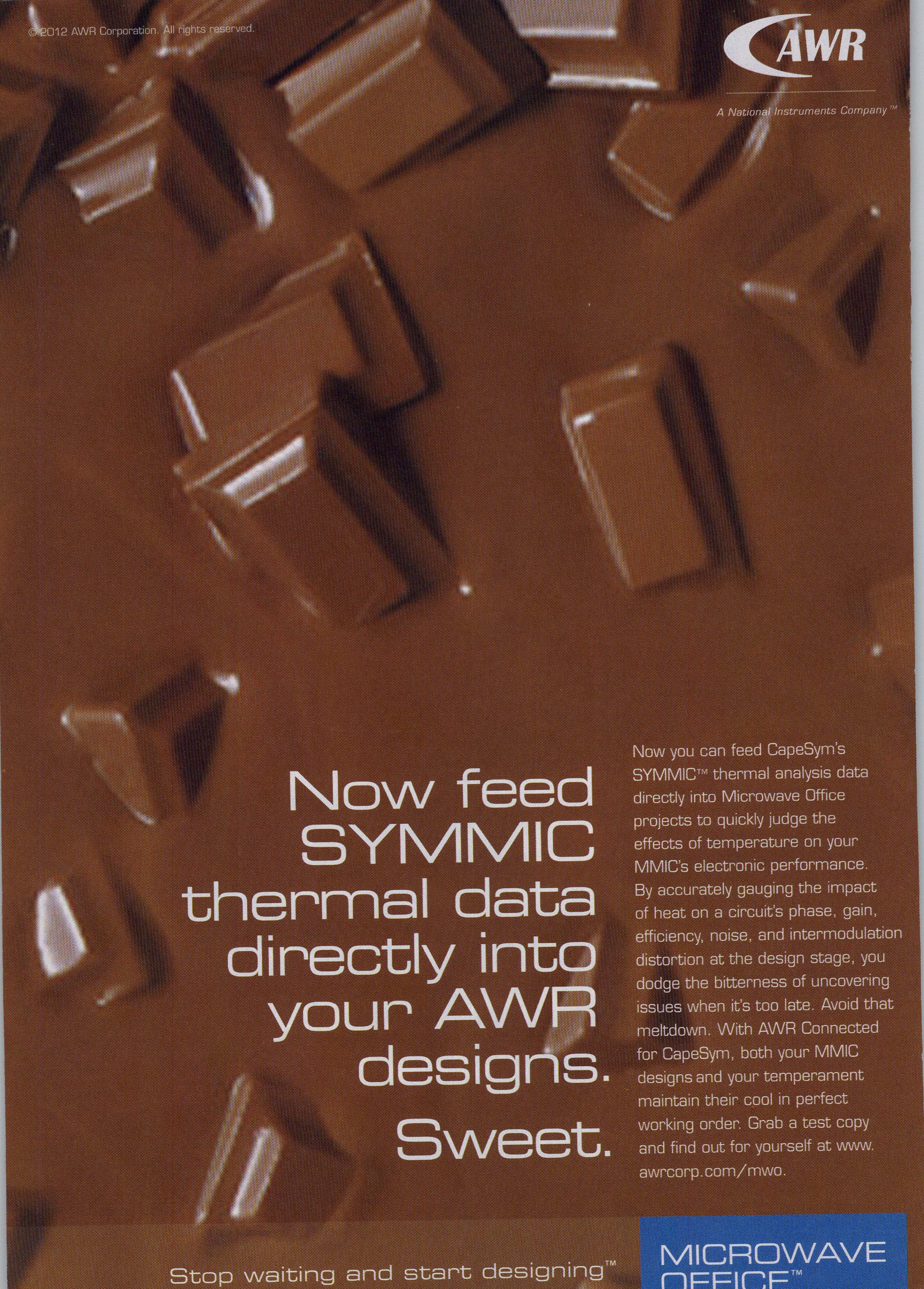

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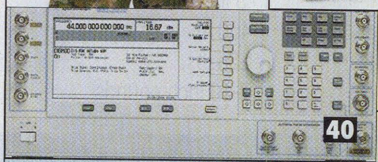

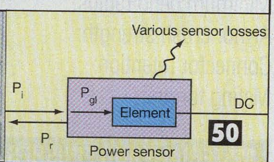

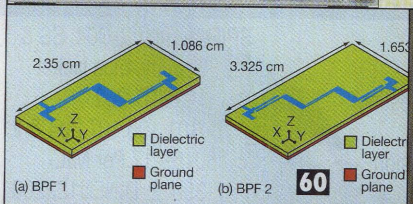

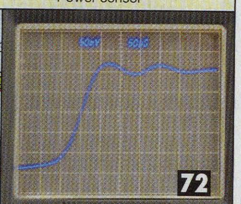

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Rosenberger® Rmor™ Cables Assembly

PHASE STABLE THROUGH 70GHz

Rosenberger Rmor™ cables are designed for rugged environments for indoor and outdoor applications. Each shielded coaxial cable is protected with flexible, SPIRAL-wound 304 Stainless Steel armor coated with extruded Polyurethane. The connector ends are sealed and encapsulated with a pressure injection-molded polymer strain relief.

This combination of materials and technology provides superior ruggedization, environmental resistance, RF shielding effectiveness and stability under flexure and vibration.

Additional connector interfaces and armor/cable diameters are available on request.

DESCRIPTION

Rosenberger connectors, cable assembly, standard length 915mm or 36 inches

GENERAL ELECTRICAL SPECIFICATIONS

Impedance:	50 +/- 1 Ohms
Operating frequency:	DC to 70 GHz
Return loss:	14 dB minimum up to 70 GHz
Cable insertion loss:	.67 dB/ft @ 10.0 GHz
Velocity of propagation (%):	78 % nominal
Capacitance:	24.7 pf/ft. nominal
Shielding effectiveness:	< -90 dB
Dielectric withstand voltage:	1000 Vrms
Amplitude & phase stable:	+/- .03dB & +/- 1° @10GHz

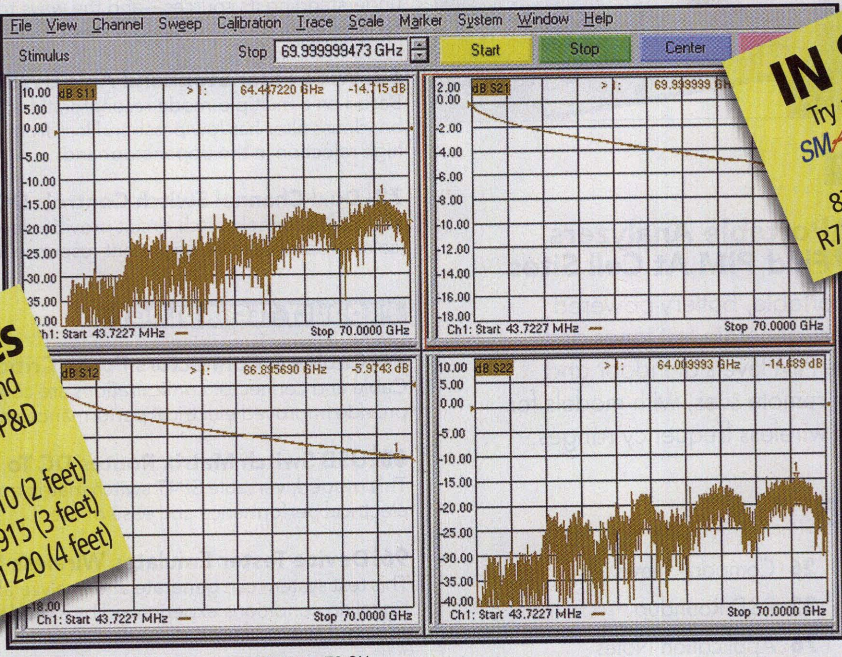
MECHANICAL SPECIFICATION

Cable jacket & armor outer diameter:	092 inches nominal & .250 inches nominal
Minimum bend radius:	.5 inches
Armor crush strength:	450 lbs/in (min)
Connector retention:	≥25 lbs.
Mating torque:	7-10 inch pounds

MATERIALS AND FINISHES

Armor type:	SPIRAL-wound 304 SS & Polyurethane blue jacket
Connector environmental testing:	Per MIL-STD-202, Meth 101,106,107,204 & 213
Connector interface dimension:	IEC 60169-17 Per MIL-PRF-39012 DINEN122200

Note: Cable assemblies also available with interfaces such as 1.85mm, 2.4mm, 2.92mm, SMA +, SMA, N.



Example of typical 36 inches assembly up to 70 GHz

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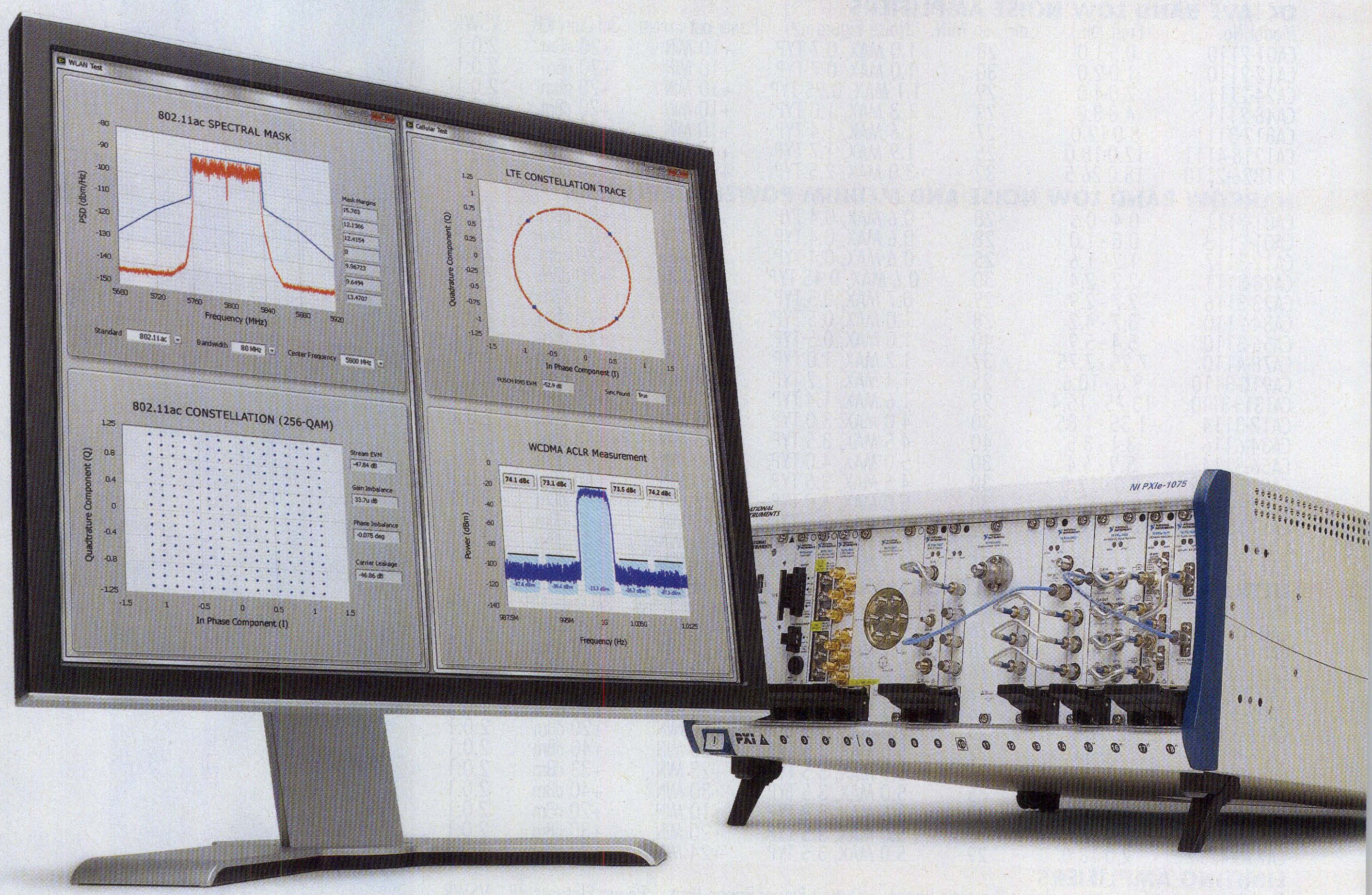

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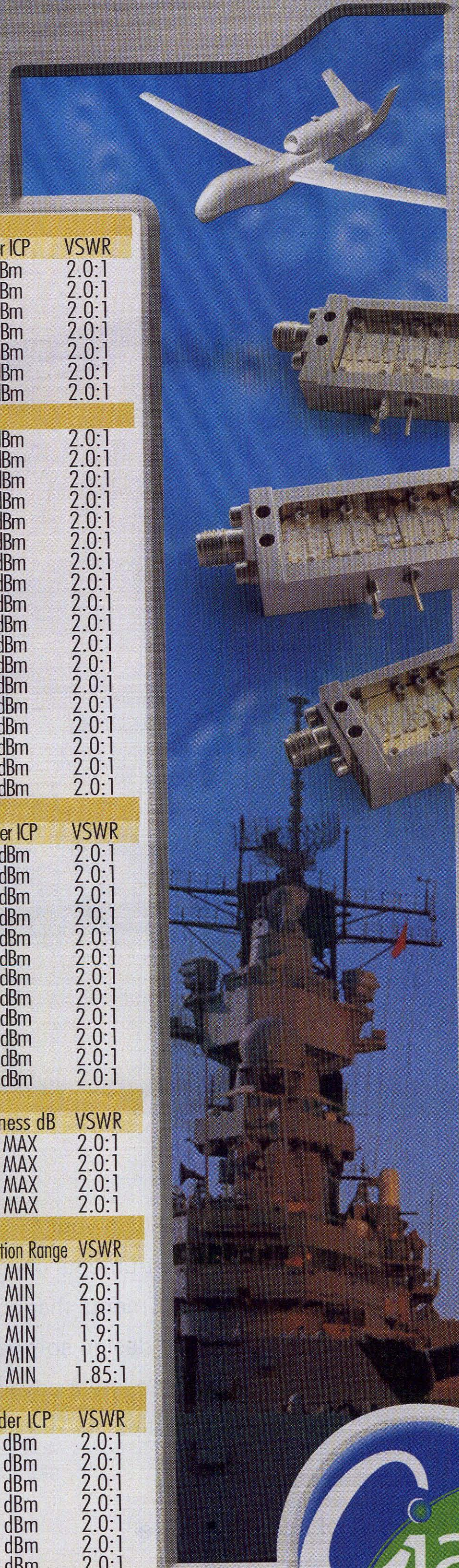

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Optimize Signal/Spectrum Analyzer Throughput For High-Volume Manufacturing Test

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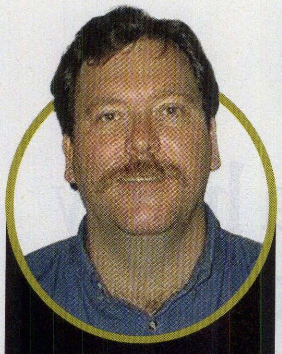
To read the article in its entirety, go to http://mwrf.com/contributors/optimize-signalspectrum-analyzer-throughput-high-volume-manufacturing-test.



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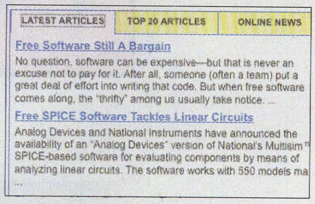

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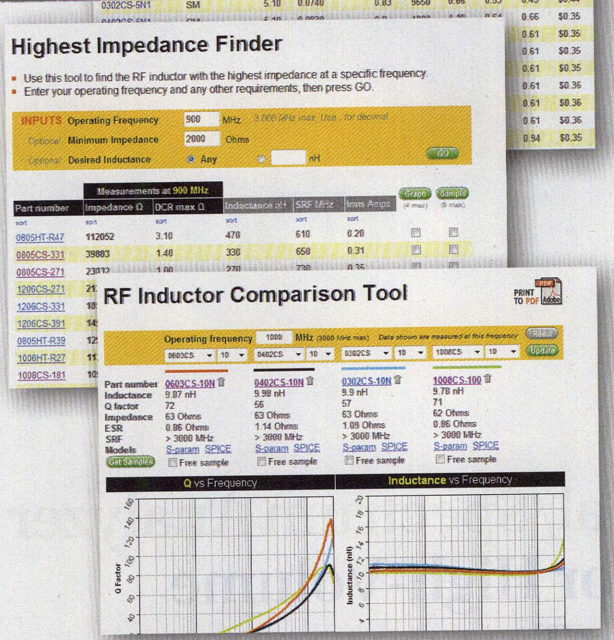

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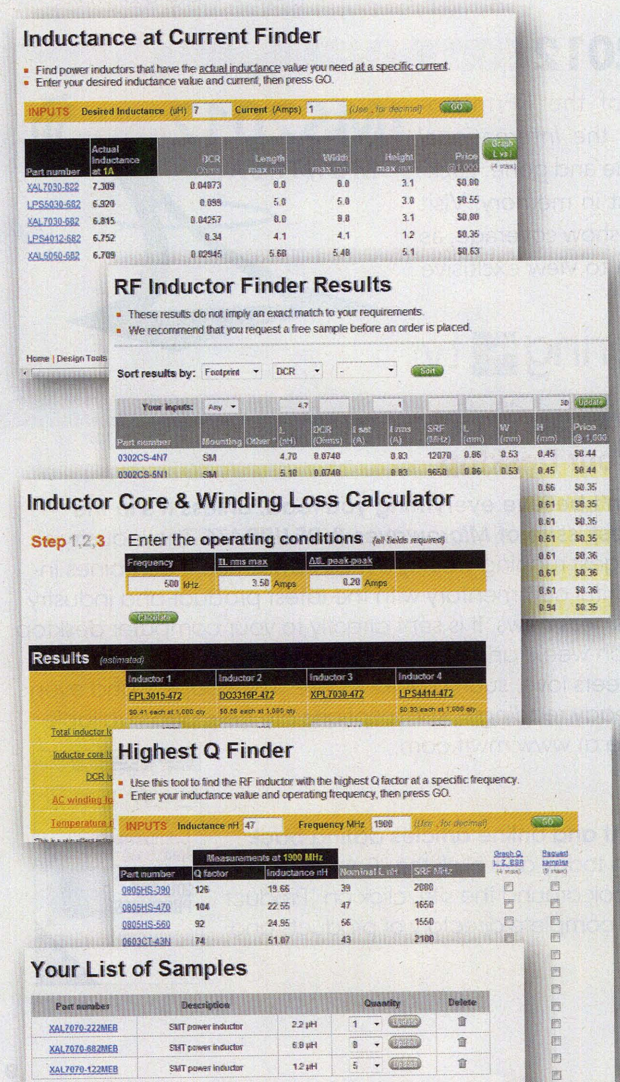

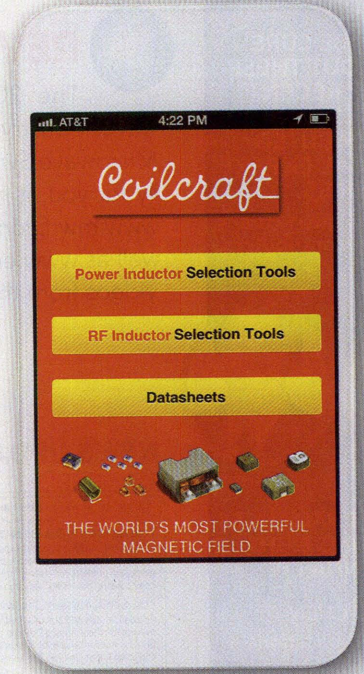

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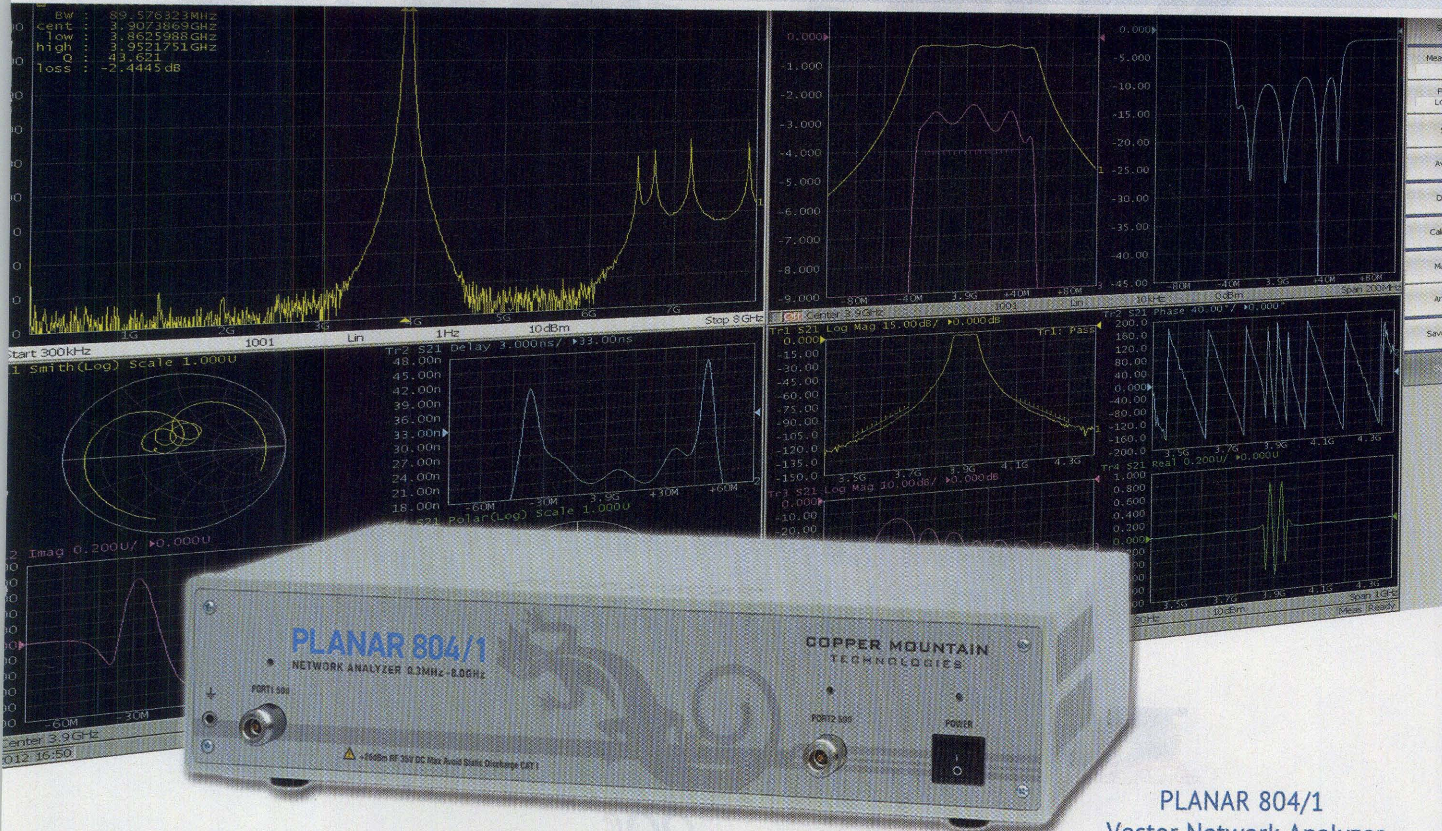

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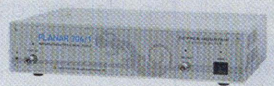
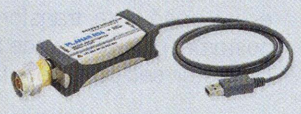


Planar 304/1
0.3 MHz - 3.2 GHz
2-port 2-path



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From the
Editor

Back When Cars Just Drove

MY LAST JOB was with a publication that focused solely on wireless technologies (a now-defunct brand titled *Wireless Systems Design*). For a January issue in the early 2000s, we chose to do a "forecast" issue covering one technology area that we thought would greatly impact the world. Our choice was telematics—a term encompassing the use of telecommunications and information-providing technologies in automobiles. A little more than 10 years later, it is clear just how appropriate that choice of subject matter was. After welcoming seemingly all of the communications technology developed and deployed in the consumer world, the automotive industry is now using it to create the car of the future.

Each automobile has evolved into its own network. Slowly but steadily, every car also is becoming part of an ad-hoc network with the cars around it. In addition, it will eventually become part of a regional network, which will allow it to communicate and receive information from different points of the city in which it is traveling.

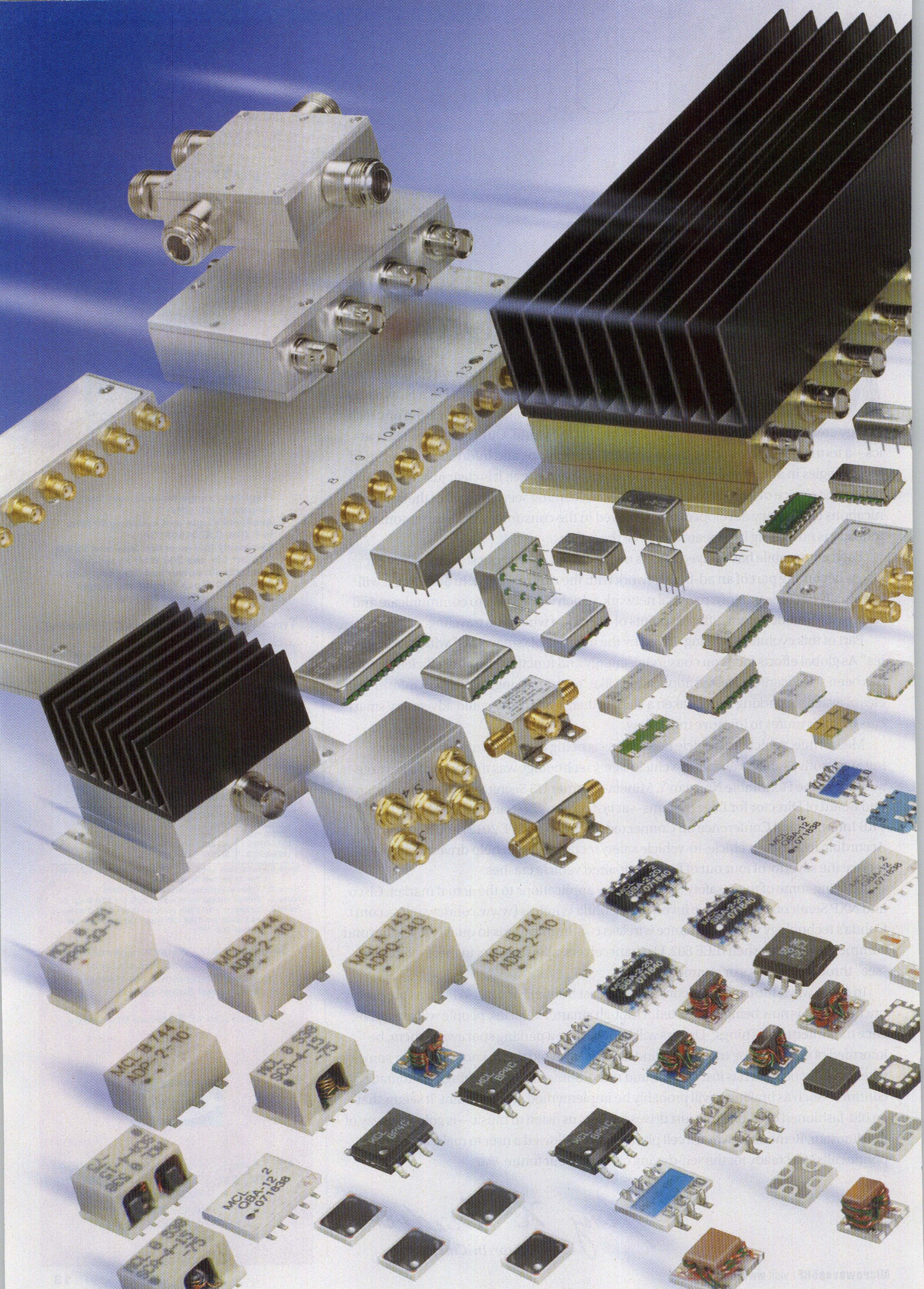
Part of this evolution is being driven by the meeting of "smart cars" with "smart cities." As global efforts focus on conserving energy and functioning more efficiently, there has been significant interest in applications like "smart parking," which will inform vehicles of available parking spots. Taken a step further, a smart city could advise any smart cars on their routes to improve traffic flow.

Meanwhile, vehicle-to-vehicle networking is being tested as a means of improving automotive safety. Vehicle-to-vehicle safety technology was the focus of a keynote address by the Honorable Norman Y. Mineta—former US Secretary of Transportation and Board of Director for Lilee Systems—at last month's first-annual ACM/ISS/IFAC/TRB International Conference on Connected Vehicles (ICCVE 2012) in Beijing, China. According to Mineta, vehicle-to-vehicle safety technology can help drivers avoid or reduce the severity of four out of five unimpaired vehicle crashes.

To bring some of these safety and efficiency applications to the actual market, Cisco and NXP Semiconductors have invested in Cohda Wireless (www.cohdawireless.com). Cohda's technology vows to enhance wireless communications to quality levels beyond commercial-off-the-shelf IEEE 802.11p transceivers, allowing cars to more effectively "see" through obstacles or around corners.

In many ways, the car can be considered a "last frontier" of sorts. What was previously unconnected is now being connected. Through smarter vehicles, people will experience the "Internet of Things." Drivers will know where a parking spot awaits them, be informed of approaching traffic jams and directed to avoid them, know that a car somewhere in front of them has lost control, and more. Somewhat frighteningly, automatic controls—such as braking—will probably be implemented at some point. It seems that an old-fashioned car—one that just drives and lets us listen to music—is going the way of the dinosaur. Remember when a cell phone simply allowed a user to make and receive phone calls? Get ready for the self-driving car; it is in our future. MWRF

Nancy K. Friedrich
Editor-In-Chief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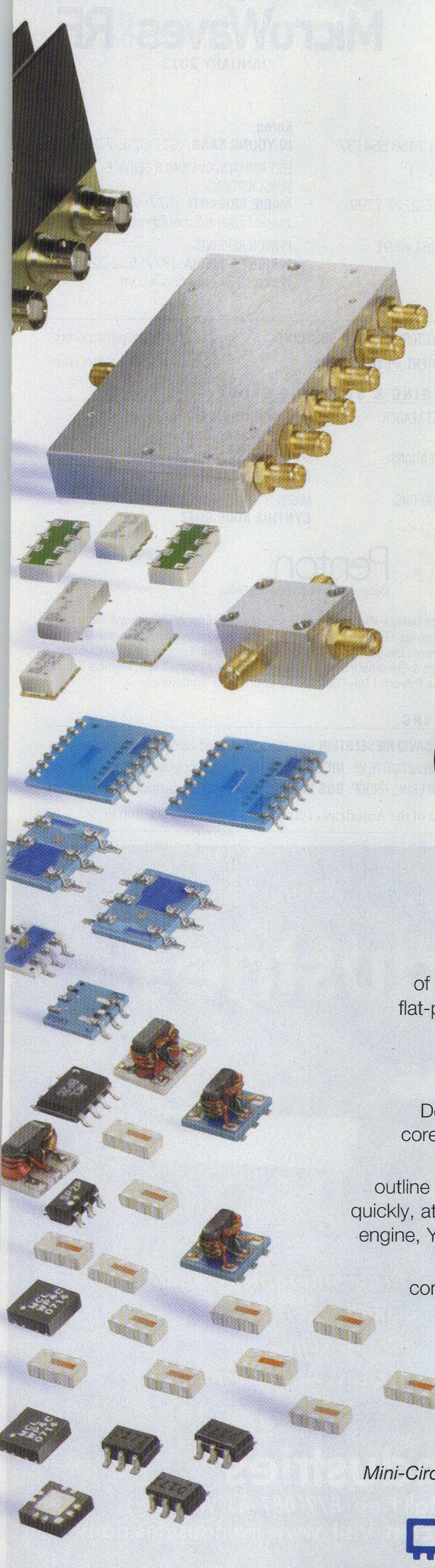

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PORTABLE TESTERS

I have long read your magazine each month for the latest news about products for RF and microwave engineers. If anything, I would like to see fewer articles in your magazine on some of the theoretical topics of coverage, and more articles devoted to new product reviews, which have more practical use to working engineers than those articles that delve into theoretical topics.

I would ask your help with a current problem and for perhaps some future guidance. In the past, it was sufficient to provide our customers with RF/microwave systems accompanied by complete electronic test reports, based on test results generated by our in-house test systems. But in recent years, many more of our customers are requesting that we perform measurements on our hardware once it has been installed in their systems. This requires that we execute on-site measurements at RF and microwave frequencies.

I am aware of some of the new portable testers being sold by leading test and measurement companies. But can these testers provide the type of accuracy and functionality that one might expect from a "standard" benchtop RF/microwave test system? And what about for pulsed characterization, such as might be needed for components being installed in a radar system? I appreciate whatever guidance the magazine can provide on the accuracy and capabilities of portable testers.

DR. ALAN DARCON
DANBURY, CT

EDITOR'S NOTE

First of all, thank you for reading. We have been seeing an increase in portable testers for this industry, when just 10 years ago most engineers would have been unwilling to risk their professional reputations (or livelihoods) on measurements made with a portable RF/microwave test instrument.

These days, however, portable RF/microwave signal sources, analyzers, and all-in-one combination testers have gained credibility—not only with the working engineers in this field, but with the agencies that must certify their use.

To help your situation, check the pages of this magazine for a future special report on portable testers and how they compare in terms of capability and accuracy to their benchtop counterparts.

Microwaves & RF welcomes mail from its readers. The magazine reserves the right to edit letters appearing in "Feedback." Address letters to:

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News

CHARGING MATS WIRELESSLY Power Military Devices

THE RACE FOR WIRELESS-CHARGING SOLUTIONS HAS BEGUN. Although such solutions are desired by consumers for their convenience, the military segment is where they will have the most profound effects. According to the US Army Research Laboratory (ARL), a soldier's load can weigh 100 lbs.—over a third of which is batteries. Alta Devices (www.altadevices.com) claims that its highly flexible technology can reduce that battery weight by 70%, shaving approximately 25 lbs. **(Fig. 1)**.

1. Based on solar cells, a series of flexible charging mats promises to make wireless charging possible for many applications.

The company just unveiled reference designs for its military charging mats **(Fig. 2)**. The 10-W charging mat, which weighs 4.1 oz., measures 10 x 11 in. when it is unfolded and 10 x 5.5 in. when it is closed. The 20-W mat measures 10 x 23 in. when open and 8 x 10 in. when closed. It weighs 10 oz. and generates up to 120 W-hrs. (Wh) energy per day. The 10-W mat can produce as much as 60 Wh/day in strong solar climates. According to Alta Devices, a typical dismounted soldier can be fully self-powered from a 20- to 30-W mat.

Each design includes specifications on size, weight, and power generated in various conditions. The designs are compliant to MIL-810-G specifications for temperature, humidity, shock, and other environmental stresses. The mats can be married to any type of battery-charging connector.

Given the myriad opportunities for wireless charging, this technology also will be introduced in unmanned systems, consumer electronics, automobiles, and a variety of industrial, remote-power applications. To give several examples, Alta's mobile power technology can be used by the following: manufacturers of unmanned aerial vehicles (UAVs) to increase flight times; industrial suppliers in the mining and exploration markets to provide remote power; and consumer-electronics makers to minimize the need to recharge. The automotive industry also will take advantage of wireless charging to provide supplemental power or increase range in vehicles of all types.

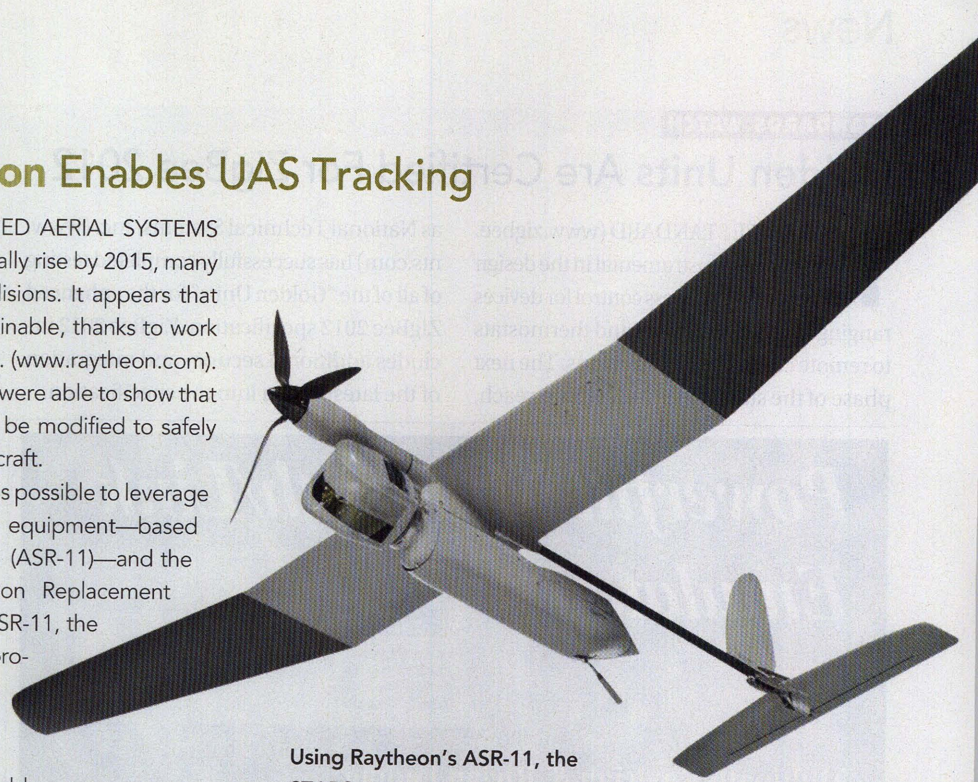
2. For soldiers on the ground, wireless charging mats can greatly reduce the weight of their packs by an estimated 70%.

Infrastructure Adaption Enables UAS Tracking

WITH THE NUMBER OF UNMANNED AERIAL SYSTEMS (UASs) in US airspace set to drastically rise by 2015, many are concerned about possible collisions. It appears that a solution to track those UASs may be attainable, thanks to work done by the US Air Force and Raytheon Co. (www.raytheon.com). In concept evaluation demonstrations, they were able to show that existing air-traffic-control equipment could be modified to safely track the presence of nearby unmanned aircraft.

Rather than invest in new infrastructure, it is possible to leverage Ground Based Sense and Avoid (GBSAA) equipment—based on the Airport Surveillance Radar Model-11 (ASR-11)—and the repurposed Standard Terminal Automation Replacement System (STARS) air-traffic-control system. ASR-11, the STARS system, and its surveillance data processor are proven, NAS-certified systems for safely separating aircraft.

The testing, which was performed near Edwards Air Force Base at Gray Butte Airfield in California, involved a moving "dynamic protection zone" (a collision-avoidance alerting capability) around the UAS. To avoid near-mid-air collisions, that zone provides a series of alerts to the UAS pilot as airborne objects (i.e., balloons or ultra-light vehicles) approach the protection zone. GBSAA also builds on risk-mitigation technology used to mitigate interference from wind turbines near airports. Leveraging the existing NAS-certified installed base of ASR-11 and STARS systems, Raytheon will continue testing GBSAA with the US Air Force at other sites across the country.



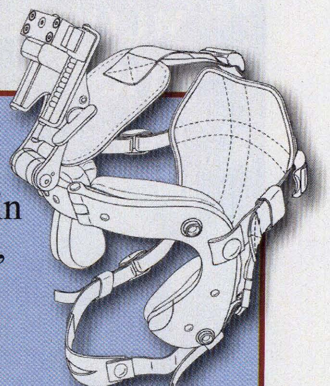
Using Raytheon's ASR-11, the STARS automation system, and its surveillance data processor (repurposed for GBSAA), pilots and controllers were given alerts of intruding airborne objects near surrogate UASs and were able to keep them safely separated.

14-nm Test Chip Eyes FinFET Process

TO SUPPORT THE CONTINUOUS MOVE to high-density, high-performance, and ultra-low-power systems-on-a-chip (SoCs) for future mobile devices, Samsung (www.samsung.com) is preparing its 14-nm FinFET process. Last month, ARM (www.arm.com) and Cadence Design Systems, Inc. (www.cadence.com) announced the tape-out of the first 14-nm test-chip implementation of the ARM Cortex-A7 processor. In addition to that processor, the test chip includes ARM Artisan standard-cell libraries, next-generation memories, and general-purpose input/output connections (I/Os).

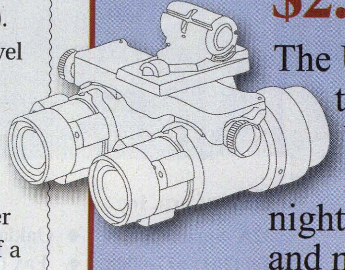
Designed with a complete Cadence register-transfer-level (RTL) -to-signoff flow, the chip is the first to target Samsung's 14-nm FinFET process. The test chip was designed using Cadence's Encounter RTL Compiler, Encounter Test, Encounter Digital Implementation System, Cadence QRC Extraction, Encounter Timing System, and Encounter Power System. The achievement of the test chip is part of a systematic program to enable ARM-technology-based SoCs on FinFET technology.

Market QUOTE



According to Visiongain (www.visiongain.com), the global market for man-portable military electronics for 2013 will be worth

$2.77 BILLION.



The US alone is expected to spend nearly $4.8 billion on devices like tactical radios, night-vision goggles, and miniature UAVs over the next decade.

STANDARDS WATCH

Golden Units Are Certified For ZigBee 2012

THE ZIGBEE STANDARD (www.zigbee.org) has been instrumental in the design of low-power wireless control for devices ranging from smart meters and thermostats to remote controls and televisions. The next phase of the standard is now within reach, as National Technical Systems, Inc. (www.nts.com) has successfully completed testing of all of the "Golden Units" for the enhanced ZigBee 2012 specification. ZigBee 2012 includes additional security and integration of the latest errata into the specification.

The Golden Units are ideal examples of this ZigBee specification. They serve as the devices by which all future ZigBee-compliant platforms will be compared for interoperability and conformance. NTS participated in the earliest stages of the interoperability testing efforts and ultimately performed all testing and verification for the new Golden Units. The lab, which was the only one chosen to perform specification R20 testing, completed testing on products from Atmel, Freescale, Silicon Labs, and Texas Instruments.

KUDOS

COMPUTER SIMULATION TECHNOLOGY (CST)—Has announced the 2012 winners of the CST University Publication Award, an annual grant to university institutes and researchers for work related to three-dimensional (3D) electromagnetic-field simulation applications: "Beamforming by Left-Handed Extraordinary Transmission Metamaterial Bi- and Plano-Concave Lens at Millimeter-Waves" by Miguel Navarro-Cía, Miguel Beruete, Igor Campillo, and Mario Sorolla Ayza; "Effects of Shape and Loading of Optical Nanoantennas on their Sensitivity and Radiation Properties" by Yang Zhao, Nader Engheta, and Andrea Alù; and "Design of a Broadband All-Textile Slotted PIFA" by Ping Jack Soh, Guy A.E. Vandenbosch, Soo Liam Ooi, and Nurul Husna Mohd Rais. The short paper winners were: "Micromachined 300-GHz SU-8-Based Slotted Waveguide Antenna" by Yi Wang, Maolong Ke, Michael J. Lancaster, and Jian Chen and "Ultraconfined Interlaced Plasmons" by Tiago A. Morgado, João S. Marcos, Mário G. Silveirinha, and Stanislav I. Maslovski.

STMICROELECTRONICS—Has been awarded the 2012 Corporate Award by the IEEE Standards Association (IEEE-SA). The award recognizes contributions to the development and advancement of standards in electrical and electronics engineering.

XILINX—Has been named 2012 Excellent Core Partner by Huawei. The award was announced at Huawei's Annual 2012 Core Partner Convention in Shenzhen, China.

PEOPLE

CRANE AEROSPACE & ELECTRONICS—GREG GOMEZ-CORNEJO has been appointed Vice President of Operations. Gomez-Cornejo previously held the position of Operations Executive for Hamilton Sundstrand, following earlier roles at Honeywell. Also, TODD WITCHALL has been appointed Vice President of Finance and Chief Financial Officer of the company's Electronics Group. Witchall comes to Crane Aerospace & Electronics from Lockheed Martin where, in his most recent role, he served as Senior Business Operations Manager.


CORNEJO

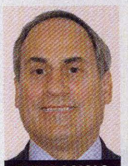

WITCHALL

SEMICONDUCTOR INDUSTRY ASSOCIATION (SIA)—The board of directors has elected AJIT MANOCHA, Chief Executive Officer for GlobalFoundries, as its 2013 chairman. In addition, DR. JOHN E. KELLY III, IBM Senior Vice President and Director of IBM Research, was elected 2013 Vice Chairman.


KELLY

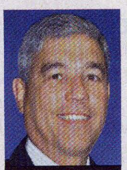
CTI TOWERS—Has appointed JIM EISENSTEIN to its board of directors. Eisenstein currently serves as Chairman and Chief Executive Officer for Grupo TorreSur, a Latin America-focused wireless tower company that he formed in 2010.

MERCURY SYSTEMS—DR. PAUL MONTICCIOLO has been appointed Chief Technology Officer. Monticciolo most recently served as President and General Manager of the company's former Mercury Federal Systems division.


MONTICCIOLO

OPTELIAN—Has named DR. JOHN YAM Asia-Pacific Regional Business Development Manager. For more than 25 years, Yam has worked with telecommunications and information-technology (IT) networking companies, among them ECI Telecom, Intel, and PCCW/Hutchison CA.

ELECTRONIC COMPONENTS INDUSTRY ASSOCIATION (ECIA)—JOHN DENSLINGER has been named President and Chief Executive Officer. Denslinger is a 40-year veteran of the electronic components industry. Prior to retiring earlier this year, he was President of SyChip, Murata's wireless solutions business.


DENSLINGER

GLOBAL SEMICONDUCTOR ALLIANCE (GSA)—Has appointed GEORGES PENALVER Regional Leadership Director for Europe, the Middle East, and Asia (EMEA). Penalver currently serves as the Executive Vice President, Corporate Strategy Officer for STMicroelectronics.

CONTRACTS

Agilent Technologies—ST-Ericsson has selected the company's RF wireless and digital laboratory solution to characterize RF transceivers.

TeleCommunication Systems (TCS)—Has received a delivery order from the US Army for Secret Internet Protocol Router and Non-secure Internet Protocol Router Access Point (SNAP) 1.2M Lite Very Small Aperture Terminal (VSAT) satellite systems. The order, which has a total value of $25 million (if all options are exercised), also includes the IMPACT tactical baseband equipment. In addition, TCS has received funding of $2.8 million from the Army for X- and Ku-Band MICRO VSAT satellite-communications equipment. This procurement is being funded through the Army's $5-billion World-Wide Satellite Systems (WWSS) contract vehicle.

RAYTHEON Snares Transatlantic Defense Orders

MDA Inks AMOS-6 Satellite Deal

Raytheon—Has been awarded $8.7 million by the US Air Force to aid in the development of the protected, tactical military-satellite-communication system. Raytheon will design and demonstrate affordable terminal components as well as support waveform development for the Air Force. In addition, Raytheon UK been awarded a contract by the UK Ministry of Defence for delivery of a new Global Positioning System (GPS) anti-jam antenna system. The order is for an undisclosed number of advanced systems to be deployed in operational theatres spanning multiple vehicle platforms.

MDA—Has signed a contract in excess of CA$100 million with Israel Aerospace Industries. MDA will supply the communications payload solution for the AMOS-6 satellite, which is slated for launch in 2015.

FRESH STARTS

dB Control—California State Senate Majority Leader Ellen Corbett recently visited the firm's 52,100-sq.-ft facility in Fremont, CA. In addition, the City of Fremont invited dBC President Fred Ortiz and Director of Manufacturing Gary Spaulding to two different strategic discussions about the state of manufacturing in Silicon Valley, the local innovation landscape, economic assets, and other topics.

AT&T—Has announced its support for the new Interoperability Compliance Program (ICP) introduced by the Wireless Broadband Alliance (WBA). The ICP is intended to create a common set of technical and commercial frameworks for WiFi roaming. In addition, AT&T recently announced that its customers recycled 50,942 wireless devices during a one-week period—a new Guinness World Record.

Agilent Technologies—Has opened a new calibration and repair service center for electronic test instruments in Hanoi, Vietnam. The new Agilent Advantage Services facility is one of more than 50 such service locations worldwide.

Atmel—Has entered into a definitive agreement to acquire Ozmo, a provider of ultra-low-power WiFi solutions. Atmel expects the transaction to close by year end and be accretive to its earnings in 2014.

Signove—Has successfully completed the Continua Health Alliance certification for its HM4A offering—an Application Host Device (AHD) supporting two wireless interfaces. This certification was performed at AT4 wireless' laboratory in Spain.

Lockheed Martin—Has acquired the assets of CDL Systems Ltd., a software engineering firm that develops and licenses vehicle-control-station software for unmanned systems. Terms of the agreement were not disclosed.

Heilind Electronics—Has acquired Interstate Connecting Components (ICC), a New Jersey-based distributor of electronic components for the military and aerospace industries.

Digi-Key Corp.—Has signed a global distribution agreement with Cicoil. The full line of Cicoil products is currently available for purchase on Digi-Key's global websites.

CTS—Has added Carpatec Complete Component (CCC) Solutions to its global sales network. CCC Solutions will represent CTS in Sweden.

Rohde & Schwarz—Has relaunched its website at www.rohde-schwarz.com. The revamped site features the company's full portfolio of 4600 products along with an optimized search function.

Anite and National Instruments—Have extended their partnership to include regional repair capability at key global locations. The two firms' present collaboration is focused on providing calibration services.

RFMW—Has relocated its headquarters in San Jose, CA. The new facility features expanded warehouse space and additional office space for product management, sales/marketing, operations, and logistics staff.

Anritsu—The company's new PIM Master MW82119A, a portable PIM test analyzer, will be distributed in the US through Talley, Inc.

RIGOL Technologies—Has been named a Strategic Member of the LXI Consortium, which includes a seat on the LXI board of directors.

Cascade Microtech—Has launched SELECTShip, a flat-rate program for logistics services. This program is available for products shipped to customers within the contiguous US. It includes door-to-door transport service, import duty, taxes, customs clearance, and other fees.

HCC Interconnect Technologies—Has launched its new website at www.hccinterconnect.com. The site offers improved navigation along with more product and application information.

FreeWave Technologies—The encryption technology within the company's Spartan series of wireless radios has been certified by the National Institute of Standards and Technology (NIST). The Spartan Series is manufactured for government and defense markets.

Tektronix—Has received accreditation from the American Association for Laboratory Accreditation (A2LA) for ISO 17025 calibration in Japan and China.

National Instruments—Is collaborating with Cardiff University on a nonlinear RF-network analysis and measurement system. The new offering combines National Instruments' PXI RF instruments and LabVIEW system design software with waveform engineering tools from Mesuro.

Inside Track with Harvey Kaylie, PRESIDENT, MINI-CIRCUITS

Interview by JACK BROWNE

Mini-Circuits Battles Back Against Sandy

The massive storm ended many businesses in the New York/New Jersey area—but motivated employees at one RF/microwave company wouldn't be deterred.

Hurricane (or "Superstorm") Sandy was one of the most expensive natural disasters to hit the United States in recent years, responsible for damages exceeding $65 billion to the mainland. Those in the New York/New Jersey metropolitan area were hit particularly hard by the storm last October, with many homes and businesses losing power and communications for more than a full week. One of this industry's leading component/test-equipment suppliers, Mini-Circuits (www.minicircuits.com), found itself particularly vulnerable to Sandy's onslaught: The firm's main office is located right at sea level in Brooklyn, NY's historic Coney Island area.

As the waters rose from the storm, neighboring streets and businesses were soon flooded. For its part, the staff of Mini-Circuits was faced with the near-impossible task of trying to carry on "business as usual" after being buried under three feet of water. In the interview that follows, Mini-Circuits President Harvey Kaylie explains how the company was able to successfully battle back against tremendous odds.

MRF: In walking around the building today, it's easy to see where the water came in, since all the drywall has been removed from about four feet down to the floor. What was it like walking in here after Sandy hit?

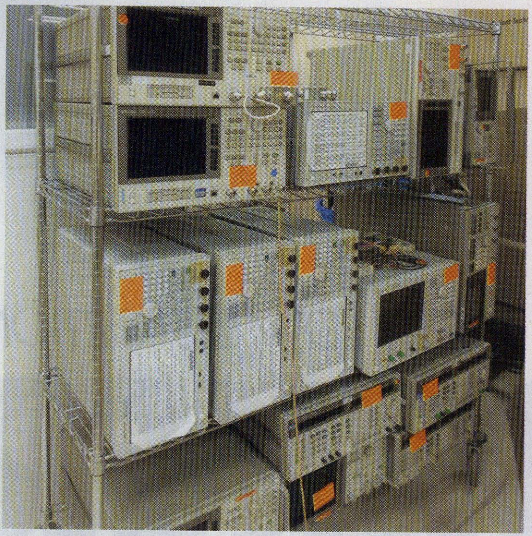
HK: The water was about three feet high, and everything that was within three feet of the floor got wet: file cabinets, test equipment, computers...even our network servers **(Fig. 1)**. We had to discard any work in progress that was below the three-foot line. The room you are in now served as the command headquarters. We set up inspection so we could see what suffered water damage and had to be discarded, and what had survived the storm **(Fig. 2)**. This was salt water, which can be very corrosive and damaging.

Our people reacted quickly after the storm. That meant getting all that water out of the building. Some people worked through the night after the storm. What was really remarkable was that two days after the storm hit, we made our shipments.

MRF: Your people are to be commended for their tremendous efforts and for putting that time into restoring the company. How did you manage the recovery?

HK: The work week was changed from Wednesday to Sunday, so that everyone worked here on the weekend in order to recover from the effects of the storm. And we kept on making progress. One big problem was getting gasoline. We also have another facility in another location, but our vans and truck that are used to transport people and goods between the two facili-

1. Damage from Sandy's three-foot-high floodwaters required the removal and disposal of the bottom half of the drywall throughout Mini-Circuits' Brooklyn, NY facility.



2. The effects from Sandy's floodwaters included damage to many of the RF/microwave vector network analyzers used for high-frequency production testing.

ties also were damaged. And then we needed to get gas, which was not readily available here in the Brooklyn area of New York City. We got gas cans from Las Vegas, NV and then we got the gas from Albany, NY. That was how we were able to function.

When the hurricane first came, we had our gas backup generator, but it does not provide enough power for the whole place—only enough for some key equipment, like the main computers. We were walking around with flashlights because of the limited power in the building. We even had a fish swimming through the hallways because of the massive amount of water we had in the building.

Then we had some replacement equipment that was delivered here from Mexico and from Japan, and we had some repair parts that we needed sent right away. We had to order new equipment. We had people coming from California and from Massachusetts to help us, to see what we had to do to keep our business going. We had to order some transformers, which we were able to get from our other facility. We relied on our disaster recovery plan, which worked out very well, and we made a great deal of progress.

We worked weekdays every night until 11 p.m. We had our own people working hard and we also got outside people helping us with repair work. That's why my office is all under renovation. And when you come next time, you'll see that's why it looks different. That's how we made progress—every day a little more.

Our software people had to work hard to restore files. Because some of our computers were damaged, along with their files, we had to send some of our equipment to an outside specialist to recover the files that we needed. In the end, we apologized to our customers for any delays the storm might have caused, but then we shipped their orders to them earlier than they might have requested, because we wanted to be clear to focus on where we needed to rebuild the company.

MRF: Did your customers understand what you were going through after the storm?

HK: I don't know. I would imagine that each one had different thoughts on what we were going through. We put a notice out on our website. As part of our recovery efforts, we wanted to make sure that communications were still flowing. We have call centers—one in Missouri and the other in Deer Park, NY—and we tried to shift phone calls to them, for which we were partially successful. So we were able to keep the communications flow going after the storm. Then, of course, our Internet and website are very important, so we put a big emphasis on making sure both were operating properly.

Everyone pitched in, and that's what it takes to recover. It takes a good plan with people who are motivated. In reality, we helped ourselves. From a manufacturing standpoint, we have fully recovered. We still are doing work on the building, but that is done in the evenings so we can keep the business going during the day. We have had to dry out the building, have it dehumidified, and have it sprayed as part of a decontamination process so that people don't get sick; we brought people in from the outside to take care of that. The bottom line is that Sandy was a big bump in the road for Mini-Circuits, but we are back now.

MRF: From the outside world, it looks like very little happened, since I think your customers have come to see Mini-Circuits as a reliable source that won't be slowed down even by a hurricane. Some of your customers may not know the hardship that the company has been through.

HK: I can tell you that right down the block from here, all the stores are closed because of damage from the hurricane. They were all flooded. We are right by the bay, and there is a narrow strip of land, and then you have the Atlantic Ocean. So you have the water from the Ocean and the Bay. There's a bridge that crosses the Bay that was destroyed. We see ships that were left on dry land. There's a major bank about four blocks from here that is still closed because of the storm.

MRF: Did you receive any official help from the government?

HK: No, we helped ourselves. We even had to get the containers for throwing out all the destroyed equipment and materials. Everything was a tremendous effort and we had to improvise. We are back in action—and we are now going strong, introducing new products. MWRF

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IF/RF MICROWAVE COMPONENTS

451 Rev J

HIS ANTENNA SYSTEM TUNES From 1.07 To 2.75 GHz

AT THE UK'S University of Sheffield, a cross bow-tie element has been created with a single-layer, dual-band, tunable high-impedance-surface (HIS) groundplane. To realize this independently tunable, low-profile antenna system in the ultra-high-frequency (UHF) band, the researchers—Hyung-Joo Lee, Kenneth Lee Ford, and Richard J. Langley—assembled it with a standard coplanar-waveguide (CPW) -fed, printed-circular-disc, wideband-monopole antenna. By making the HIS groundplane tunable, the engineers surmised that they could achieve a wider effective bandwidth.

The groundplane and wideband antenna were fabricated with 1SV245 varactor diodes from Toshiba (www.toshiba.com). The antenna system showed an effective tunable bandwidth of roughly 0.9 to 2.8 GHz with dual-band capability. By performing simulations of the HIS groundplane, the researchers showed that either single- or dual-band reconfigurable reflection-phase resonances could be achieved between 0.95 and 2.45 GHz by controlling C1 (4.55 pF~0.6 pF) and C2 (4.55 pF~0.6 pF) independently. (These represent the two groups of varactor diodes mounted on the surface elements of the HIS.)

According to simulations performed with the wideband antenna 4 mm above the HIS groundplane, an effective, tunable operational bandwidth from 1.07 to 2.75 GHz is achievable with dual-band capability. The proposed HIS groundplane features a unit cell measuring 19.71 by 19.71 mm and 1.74 mm thick. See "Independently Tunable Low-Profile Dual-Band High-Impedance Surface Antenna System for Applications in UHF Band," *IEEE Transactions On Antennas And Propagation*, Sept. 2012, p. 4092.

ZERO-IF GFSK Demodulator Consumes Just 190 μW

WHEN USED in low-power transceivers with Gaussian-frequency-shift-keying (GFSK) modulation, zero intermediate-frequency (IF) architectures remain robust in the face of quadrature imbalances. They also allow for a simple low-pass filter to reject adjacent channels. Although a low-power transceiver calls for zero-IF GFSK demodulators, such demodulators typically require two power-hungry analog-to-digital converters (ADCs). At Spain's Institute of Microelectronics of Seville, a GFSK demodulation scheme with phase rotation was proposed by Jens Masuch and Manuel Delgado-Restituto. Rather than requiring resistors, this approach combines the weighted outputs of current mirrors.

The demodulator is based on a phase-domain ADC (Ph-ADC). It directly quantizes the phase information of the received complex baseband signal. In addition, the Ph-ADC linearly combines the in-phase/quadrature (I/Q) aspects of the incoming signal. To detect the zero crossings and build a 4-b digital representation of the signal phase, the generated phase-shifted versions are fed to comparators.

The proposed solution employs a resistor-less scheme, which performs phase rotations in the current domain. In addition to reducing the amplitude error of the phase rotation, the demodulator permits an area-efficient implementation. With the Ph-ADC, the integrated GFSK demodulator houses a channel-filtering programmable-gain amplifier (PGA) and a symbol decision block while occupying just 0.14 mm^2. The I and Q signals are first filtered and equalized with the two-stage PGA over a dynamic range of more than 50 dB. Because the subsequent Ph-ADC only evaluates phase information, the PGA simply implements coarse gain steps of 6 dB.

The demodulator consumes 190 μW from a 1-V supply. For a 1-Mb/s data rate and 0.5 modulation depth, it demands an E_B/N_O of 14.8 dB for a bit-error rate of 0.1% considering a flicker noise corner of 150 kHz. It boasts 74 dB dynamic range and can tolerate carrier-frequency offsets of ±170 kHz. See "A 190-μW zero-IF GFSK Demodulator with a 4-b Phase-Domain ADC," *IEEE Journal Of Solid-State Circuits*, Nov. 2012, p. 2796.

RFID Tag Antenna Can Read Beyond 9 m

AN ULTRA-HIGH-FREQUENCY (UHF), passive RF-identification (RFID) tag typically comprises an antenna and an application-specific integrated circuit (ASIC). Most RFID tags must be attached to small objects and different surfaces, which limits the tag antenna in both size and gain. At Taiwan's National Kaohsiung University of Applied Sciences, a UHF RFID tag antenna with dual-polarization reading patterns on safety-glass objects has been proposed by Yi-Fang Lin, Shu-An Yeh, Hua-Ming Chen, and Sue-Wei Chang.

That UHF RFID tag antenna comprises a trapezoidal loop and a dual-dipole radiator with an L-slit for omnidirectional polarized reading patterns. The orthogonal dual-dipole tag antenna with an L-slit on each dipole arm ensures a conjugate match to the Monza 3 microchip impedance of 44 – j231 Ω at 915 MHz. Antenna resistance and inductive reactance are easily controlled with simple size adjustments of the L-slit and dipole radiator. A prototype attached on a different glass read beyond 9 m. It was tested for an RFID reader with 4.0 W effective isotropic radiated power (EIRP). See "Design of an Omnidirectional Polarized RFID Tag Antenna for Safety Glass Applications," *IEEE Transactions On Antennas And Propagation*, Oct. 2012, p. 4530.

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IF/RF MICROWAVE COMPONENTS

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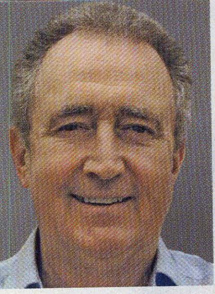


Microwaves in Europe

PAUL WHYTOCK, *European Editor*

In-Vehicle Wireless Charging Hits The Road… Without Jack (Or Plug)

Toyota's Avalon will feature a wireless charging system. Using Qi and RFID technology, it lets drivers charge their smartphones while driving. All the driver does is place his or her Qi-protocol-enabled phone onto a charging mat built into the dash panel.

WORLDWIDE CAR PRODUCTION reached approximately 80 million units in 2012. Because of the relentless escalation of the vehicle population, it is important for in-car induction systems to be able to charge a broad range of devices—regardless of brand, manufacturer, or type of device. This is a key design consideration for vehicular infrastructures, where the diversity of user devices is high. To allow drivers to charge their smartphones while driving, an in-vehicle wireless charging system using Qi and RF-identification (RFID) technology has been designed into the Toyota Avalon.

In this use case, all the driver does is place a Qi-protocol-enabled phone onto a charging mat, which forms part of the vehicle's dash panel. This capability will be available in Avalon models released later this year. Qi wireless charging is currently available in 34 mobile-phone models. Here, the backwards compatibility of the Qi standard is critical, as it will ensure that the seamless charging experience is maintained as Qi technology evolves.

In 2008, the Wireless Power Consortium (www.wirelesspowerconsortium.com) signed an agreement for an open standard for wireless power. Called Qi, it is based on induction charging technology that involves transmitting energy via a magnetic field. Specifically, devices that operate with the Qi standard rely on magnetic induction between planar coils.

Two kinds of devices are involved: base stations, which provide inductive power, and mobile devices that consume inductive power. The base station has a power transmitter comprising a transmitting coil. In contrast, the mobile device has a power receiver that contains a receiving coil. Close spacing of the two coils—as well as shielding on their surfaces—ensures efficient inductive power transfer. The use of appropriate shielding is important because it reduces the driver's long-term exposure to the electromagnetic field.

Qi power efficiency is typically claimed to be 70%. However, efficiency can drop to 40%, depending on the distances involved in the power transfer. In general, inductive charging has faced challenges due to lack of efficiency and increased resistive heating. In comparison to direct-contact charging methods, it also is more expensive in equipment terms. After all, it requires additional electronics and coils both in the device and charger.

Typically, these systems also are criticized because the device being charged has to stay positioned on the charging mat. When it comes to the in-vehicle use of wireless charging, however, this limitation actually offers a benefit: Unlike cable-connected recharging methods, it prevents drivers from using the phone while driving.

UNLOCKING AVALON'S CHARGING SYSTEM

The Avalon's wireless-charging system relies on technology developed by Hong Kong-based ConvenientPower (www.convenientpower.com) and Philips & Lite-On Digital Solutions (PLDS; www.pldsnet.com). ConvenientPower is a specialist in wireless power charging and related intellectual property (IP). It co-designed Qi and co-founded the Wireless Power Consortium, which now has about 100 members including Samsung, Nokia, HTC, Motorola Mobility, and Sony. For its part, Philips & Lite-On Digital Solutions designs and develops optical-disc-drive products for automotive applications. Its major research center is in Germany.

An important element in the continuing implementation of induction charging is ensuring that systems can recognize different products and how much charge they need. Israeli company Powermat (www.powermat.com) uses RFID tags to identify what is being placed in the charging position. The RFID tags are held in a case made to fit around popular gadgets like iPods, laptops, and mobile phones. When a gadget is positioned on a Powermat, it reads the RFID tag to identify the device and ensure that it receives only the charge it requires.

Toyota is predicting sales of 70,000 for its Avalon vehicles in 2013. If that estimate is reached, the car will probably be a bigger hit than the music single "Avalon" by Roxy Music.

JACK BROWNE | Technical Contributor

KEEPING PACE WITH Microwave Test Needs

MEASUREMENT TECHNOLOGIES ARE BECOMING EASIER TO TRANSPORT WHERE NEEDED, THANKS TO AN INCREASE IN PORTABLE INSTRUMENTS AND A GROWING ADOPTION OF MODULAR CONFIGURATIONS.

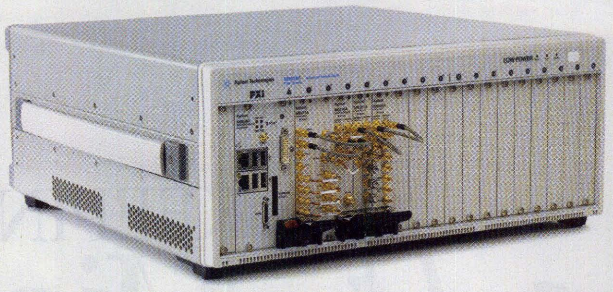
1. Anritsu's PIM Master [Photo courtesy of Anritsu Co. (www.anritsu.com).]

MICROWAVE/RF MEASUREMENT CAPABILITIES must keep up with the industry's many technologies to be effective. Over the past decade, the advances in communications technologies alone have been enough to challenge the most adroit test-and-measurement equipment designers. With the wide range of wireless communications formats now available—from narrowband channels with complex digital modulation to ultrawideband (UWB) communications systems—developers of measurement products have been seriously challenged to provide practical solutions. But as this brief look at recent trends in RF/microwave test equipment will show, many of those measurement solutions provide uncommon combinations of performance and low price.

One trend is for an increase in on-site measurements, feeding a requirement for an increasing number of portable RF/microwave instruments. Some of the major names in high-frequency test solutions have responded to this market need in a big way: Agilent Technologies (www.agilent.com) offers its portable FieldFox spectrum and vector network analyzers (VNAs). Anritsu Co. (www.anritsu.com), having introduced its Site Master portable RF/microwave testers almost one decade earlier, recently released its lines of PIM Master analyzers (see Cover Story, p. 78) for on-site measurements of passive intermodulation (PIM) at cell sites and antenna towers.

The handheld FieldFox analyzer series from Agilent includes different models operating from 30 kHz to 4.0, 6.5, 9.0, 14.0, 18.0, and 26.5 GHz. They are available as portable VNAs or spectrum analyzers, or as combinations of the two functions, and can also be equipped with a cable and antenna analyzer. These portable instruments typically weigh only 6.6 lbs (3.0 kg) and can provide as much as 3.5 hours of battery life on a charge.

The MW82119A family of PIM Master portable instruments from Anritsu Co. use a 8.4-in. touchscreen display as their control center, with models for different communications bands; among these are Long Term Evolution (LTE) cellular and the Personal Communications Services (PCS) bands. These battery-powered analyzers weigh less than 27 lbs.



2. These modules create a modulated frequency synthesizer. [Photo courtesy of Agilent Technologies (www.agilent.com).]

and measure only 13.8 x 12.4 x 6.0 in. (350 x 314 x 152 mm) and will operate for more than 2.5 hours on a battery charge **(Fig. 1)**.

While these are two of the better-known names in RF/microwave test, they are not the only ones with portable, handheld RF/microwave instruments: A number of additional firms, including Aeroflex (www.aeroflex.com) and Rohde & Schwarz (www.rohde-schwarz.com), offer portable spectrum analyzers and vector network analyzers. The 9100 series of portable spectrum analyzers from Aeroflex includes models from 10 kHz through 7.5 GHz. The model 9103, for example, spans 100 kHz to 7.5 GHz with 1-kHz resolution bandwidth and –117 dBm displayed average noise level (DANL). The 9100 series analyzers are designed to be brought to test sites, with a small size of 14.0 x 7.5 x 4.1 in. (355 x 190 x 104 mm) and weight of only 8 lbs (3.6 kg) with battery.

The R&S® ZVH line of cable and antenna analyzers from Rohde & Schwarz (www.rohde-schwarz.com) has long been a fixture in the cable-television and communications industries for repair and maintenance. With models available from 100 kHz to 3.6 GHz and 100 kHz to 8 GHz, this analyzer has especially been designed for use in the field. It is capable of distance-to-fault measurements and one-port cable loss measurements to simplify troubleshooting in the field.

Kaelus (www.kaelus.com; the former Summitek Instruments), has long provided portable measurement solutions for on-site PIM testing, in the form of its iMT series portable IMD analyzers. Several models are available for different transmit frequencies, including the 850-MHz band. The testers use two 20-W (+43-dBm) tones at different frequencies to test for PIM.

Another compact portable instrument is the DeviScope 200SA spectrum analyzer from Deviser Technology Ltd. (www.deviser.com). The analyzer, which runs for more than two hours on a battery charge, spans 1 MHz to 18 GHz but weighs less than 7 kg and measures only 313 x 211 x 87 mm.

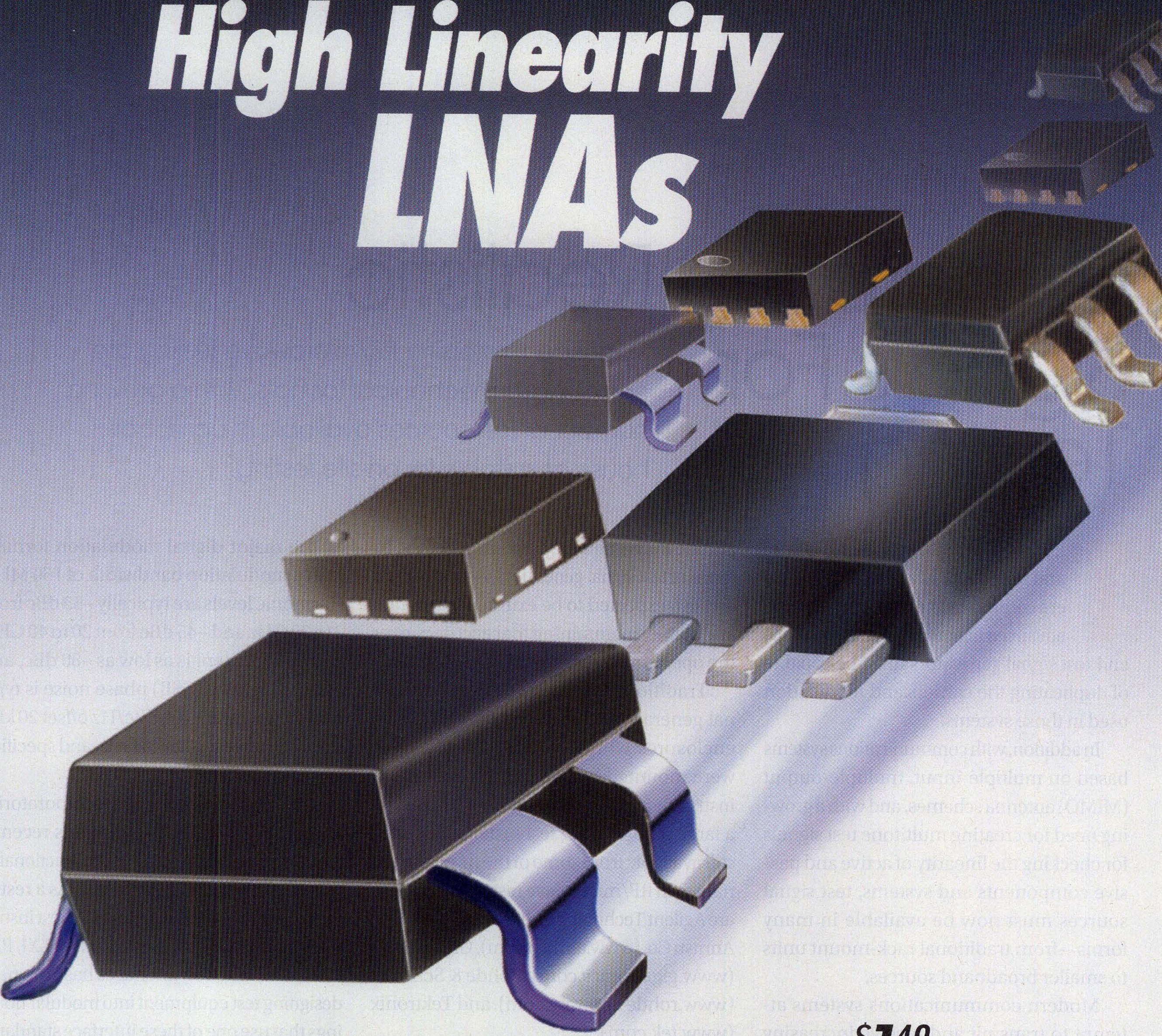
Models H600 and SA2600 from Tektronix (www.tek.com) are also portable spectrum analyzers, both with 20-MHz capture bandwidth from 10 kHz to 6.2 GHz, with spurious-free dynamic range (SFDR) approaching 70 dB. They are built according to MIL-PRF-28800F and are ideal for spectrum monitoring and surveillance.

In addition to making measurement functions smaller, many instrument manufacturers are making their products in modular form, simplifying the integration of multiple functions into a rack or even into a single chassis. Agilent showed a PXI vector analyzer **(Fig. 2)** at last year's International Microwave Symposium (IMS) in Montreal, Canada based on PXI Express (PXIe). It provides four channels from 10 MHz to 26.5 GHz and instantaneous bandwidths as wide as 1.5 GHz (see the August 2012 issue, p. 102).

National Instruments (www.ni.com), a leader in making modular instruments, has added to its legacy with additional PXI function modules, controllers, and chassis. The firm even provides an online advisor for those seeking to build a modular PXI measurement system.

Finally, in some instances, measurement advances are made by means of enhancements to test methods and calibration techniques rather than to the equipment itself. For example, ATE Systems (www.atesystems.com) has developed unique methodologies for improving the accuracy of VNA measurements, allowing a VNA system to be calibrated at any time without user intervention. MWRF

High Linearity LNAs



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PMA-5452+	50-6000	14.0	0.7	34	18	40	1.49
PSA4-5043+	50-4000	18.4	0.75	34	19	33 (3V) 58 (5V)	2.50
PMA-5455+	50-6000	14.0	0.8	33	19	40	1.49
PMA-5451+	50-6000	13.7	0.8	31	17	30	1.49
PMA2-252LN+	1500-2500	15-19	0.8	30	18	25-55 (3V) 37-80 (4V)	2.87
PMA-545G3+	700-1000	31.3	0.9	33	22	158	4.95
PMA-5454+	50-6000	13.5	0.9	28	15	20	1.49

Model	Freq. (MHz)	Gain (dB)	NF (dB)	IP3 (dBm)	P_{out} (dBm)	Current (mA)	Price $ (qty. 20)
PGA-103+	50-4000	11.0	0.9	43	22	60 (3V) 97 (5V)	1.99
PMA-5453+	50-6000	14.3	0.7	37	20	60	1.49
PSA-5453+	50-4000	14.7	1.0	37	19	60	1.49
PMA-5456+	50-6000	14.4	0.8	36	22	60	1.49
PMA-545+	50-6000	14.2	0.8	36	20	80	1.49
PSA-545+	50-4000	14.9	1.0	36	20	80	1.49
PMA-545G1+	400-2200	31.3	1.0	34	22	158	4.95
PMA-545G2+	1100-1600	30.4	1.0	34	22	158	4.95
PSA-5455+	50-4000	14.4	1.0	32	19	40	1.49

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506 rev C

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Generating Realistic Signals For Testing

Signal generators for RF/microwave testing are changing in mechanical formats, with a growing number of test sources available in compact housings suitable for on-site testing.

TEST SIGNALS MUST be accurate, and they must also be stable. Modern communications systems employ advanced digital modulation formats, and test signal generators must be capable of duplicating the carriers and modulation used in those systems.

In addition, with communications systems based on multiple-input, multiple-output (MIMO) antenna schemes, and with a growing need for creating multitone test signals for checking the linearity of active and passive components and systems, test signal sources must now be available in many forms—from traditional rack-mount units to smaller broadband sources.

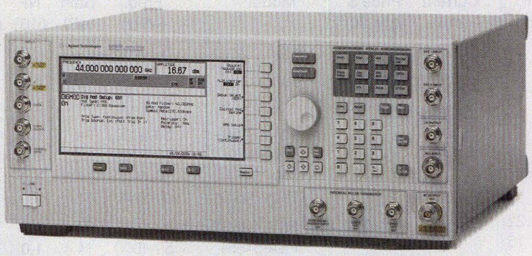
Modern communications systems attempt to transmit and receive increasing amounts of information through the use of digital modulation schemes, such as amplitude-shift-keying (ASK), frequency-shift keying (FSK), phase-shift keying (PSK), and quadrature amplitude modulation (QAM). The latter can be generated with at least two signal components that are out of phase—such as in-phase (I) and quadrature (Q) components—with digital bits transmitted by different relative states or symbols formed by the signal components.

To characterize the many active and passive components in the receiving and transmitting portions of these modern communications systems, test-equipment manufacturers must recreate the types of digitally modulated signals used in the systems, in terms of the bandwidth of interest, amplitude range, and modulation schemes. In terms of test signal generators, output signals are also expected to be extremely accurate and stable, maintaining that accuracy over the operating lifetime of the signal source.

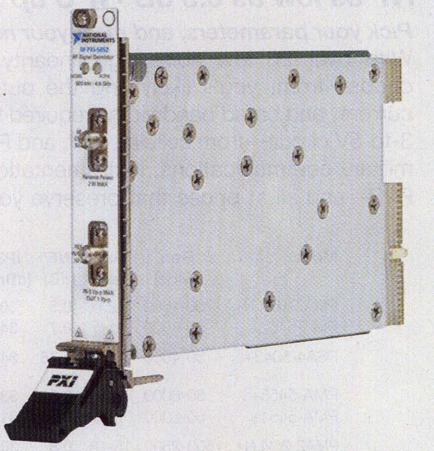
Traditionally, RF/microwave test signal generators have been housed in large enclosures which sat on a benchtop or were mounted in a 19-in. rack with other instruments. Such signal generators are still a large part of many test installations, and still available from some of the more trusted names in RF/microwave test. Among these are Agilent Technologies (www.agilent.com), Anritsu Co. (www.anritsu.com), Giga-tronics (www.gigatronics.com), Rohde & Schwarz (www.rohde-schwarz.com), and Tektronix (www.tek.com).

For example, the E8267D PSG signal generator from Agilent Technologies **(Fig. 1)** is available with a frequency range of 250 kHz to 44 GHz that can be tuned or swept with 0.001 Hz resolution. It can be set to minimum output power of –130 dBm, with output levels as high as +23 dBm to 20 GHz and +18 dBm to 40 GHz. It provides all the major digital modulation formats with a modulation bandwidth of 160 MHz. Harmonic levels are typically –55 dBc from 2 to 20 GHz and –45 dBc from 20 to 40 GHz. Spurious content is as low as –80 dBc, and single-sideband (SSB) phase noise is typically better than –100 dBc/Hz offset 20 kHz from carriers through 44 GHz, and specified at –124 dBc/Hz through 2 GHz.

Abandoning tradition, test laboratories and production test departments recently have sought more measurement functionality from a given space in a test rack. As a result, the popularity of smaller, modular test instruments communicating by means of LXI, PXI, VME, VXI, and USB interfaces has grown. By designing test equipment into modular housings that use one of these interface standards



1. This signal generator is an example of the traditional benchtop housing. This unit operates from 250 kHz to 44 GHz with a host of modulation capabilities. [Photo courtesy of Agilent Technologies (www.agilent.com).]

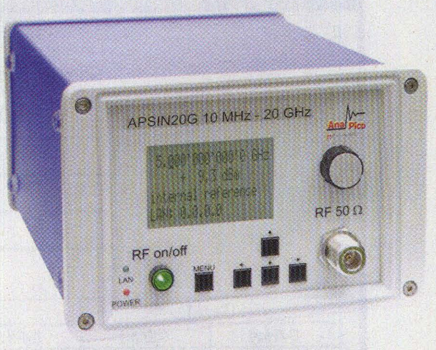


2. This compact module is representative of RF/microwave instrument functions in PXI form. It is one of a series of units capable of generating signals to 6.6 GHz. [Photo courtesy of National Instruments (www.ni.com).]

to communicate, test instrument suppliers can pack multiple functions into a space once occupied by a single function.

The modular approach makes it possible, for example, to assemble a rack of test equipment with multiple signal generators to generate two-tone or multitone test signals useful for linearity testing of components. These modular collections of instruments are typically controlled by an additional personal computer (PC) under the command of a dedicated measurement program.

One such series of modular signal generators is the NI 565x series from National Instruments (www.ni.com), which is based on the PXI format. Several of these test signal modules **(Fig. 2)** can be slid into a PXI chassis with a control module to create. Signal generator modules are available through 6.6 GHz. By adding frequency upconversion modules, such as the firm's model NI 5610 module, the frequency range can be extended further. The company also offers PXI arbitrary-waveform-generation (AWG) modules for creating complex modulation formats, as well as a single vector-signal-generator module (model PXIe-5673E) based on the high-speed PXI-Express (PXIe) interface.



3. The model APSIN20G signal generator can be controlled by numerous interfaces and provides clean outputs from 9 kHz to 20 GHz. [Photo courtesy of AnaPico (www.anapico.com).]

In addition to the transformation from benchtop instruments to modules, modern RF/microwave signal generators are available increasingly as portable and even battery-powered units designed for use in the laboratory as well as for on-site testing. Some of these test signal sources are being developed by firms once thought of as "components suppliers."

For example, Hittite Microwave Corp. (www.hittite.com) has developed the portable model HMC-T2270 synthesized signal generator with a range of 10 MHz to 70 GHz—impressive considering it fits in a housing measuring only 12 x 8 x 3 in. (305 x 203 x 76.2 mm) and weighing only 8.25 lbs (3.7 kg). The portable source delivers +29 dBm output power at 1 GHz and +3 dBm output power at 70 GHz. In spite of the small size, it features laboratory-grade performance, with SSB phase noise of –118 dBc/Hz offset 10 kHz from a 1-GHz carrier and –79 dBc/Hz offset 100 kHz from a 67-GHz carrier.

The model SSG-4000HP synthesized signal generator from Mini-Circuits (www.minicircuits.com) lacks the carrying handle,

but is similarly compact and provides output signals from 250 to 4000 MHz with a 70-dB dynamic range of –50 to +20 dBm. It is powered by an external +24-VDC supply and uses a USB interface.

Two companies offering small-signal generators that are not components suppliers—AnaPico AG (www.anapico.com) and Vaunix (www.vaunix.com)—boast small sources that are suitable for creating multitone sources for such applications as MIMO testing and linearity measurements. The model APSIN20G from AnaPico, for example, is a broadband unit measuring just 172 x 220 x 106 mm but capable of outputs from 9 kHz to 20 GHz **(Fig. 3)**.

Vaunix is one of the few signal generator supplies that offers sources that can be not only controlled by a USB connection, but powered by it as well. Measuring just 4.90 x 3.14 x 1.59 in. (124 x 80 x 40 mm) and weighing less than 1 lb. (0.45 kg), the firm's Lab Brick LSG and LMS lines of signal generators can also operate by means of a battery or external power supply for non-USB applications. The LSG series includes models in bands from 20 MHz to 6 GHz while the LMS series is comprised of a number of units in bands from 0.5 to 20.0 GHz.

These higher-frequency Lab Brick sources, while lacking digital modulation capabilities, can be supplied with optional pulse modulation for radar testing. They offer excellent electrical performance in spite of low power consumption. A model LMS-402D, which operates from 1 to 4 GHz, has phase noise of –98 dBc/Hz offset 10 kHz from any carrier, while a model LMS-203, with output signals from 10 to 20 GHz, has phase noise of –75 dBc/Hz offset 10 kHz from any carrier.

A relative signal-generator newcomer, Pronghorn Solutions (www.pronghorn-solutions.com), has developed a compact, low-power source suitable for using in groups to generate multitone test signals. The firm's model PHS-3000 operates from 150 MHz to 9 GHz in a housing measuring just 3.5 x 5.5 x 1.25 in. and weighing less than 2.5 lbs. It can be powered by means of 110 VAC using an external power supply and can also run 4 hours on its internal battery.

These "pocket-sized" signal generators provide clean, basic output signals that can be readily combined through an N-way power divider, with each signal generator tuned to the desired offset to create a wide range of multiple-tone signals. While generating such signals with traditional benchtop/rack-mount signal generators would be cost-prohibitive, these smaller signal generators can often accommodate such multitone testing at the cost of one or two traditional test signal sources. MWRF

Editor's Note: To read an expanded version of this article, go to http://mwrf.com/test-amp-measurement-analyzers/generating-realistic-signals-testing.

JACK BROWNE | Technical Contributor

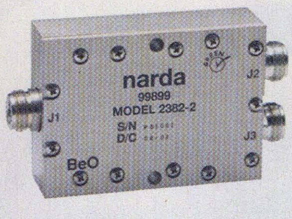
Components Aid Broadband Testing

Broadband active and passive components can perform invaluable signal-processing and translation functions, both in manual and automatic RF/microwave measurement systems.

ACCURATE MICROWAVE MEASUREMENTS require the right test equipment, but often more than that. Sometimes, additions are needed for optimum performance and/or functionality from the test setup. These additions often come in the form of power dividers/combiners, switches, filters, amplifiers, and other broadband components that can in some way help to make the measurements easier.

The definition for "broadband," as in broadband components, has somewhat flexible meaning depending upon the application of interest. In most cases, broadband will mean a frequency range that exceeds the frequency span of the application to be tested. Many of the suppliers mentioned in this article offer numerous kinds of high-frequency components with wide frequency ranges. In most cases, custom versions of components are available.

Power dividers are among the more useful broadband components in a test laboratory, and available in many package forms. For example, model P2D180900L is a two-way power divider from Synergy Microwave Corp. (www.synergymwave.com) that spans 1800 to 9000 MHz with less than 1.2 dB insertion loss through 8 GHz. Supplied in a compact RoHS-compliant surface-mount package, this power divider can be used to construct a broadband test fixture for use with high-frequency analyzers.



This is an example of a broadband two-way power divider suitable for splitting signals in test setups. It spans 0.5 to 6.0 GHz and can handle as much as 250 W CW input power. [Photo courtesy of Narda Microwave East (www.nardamicrowave.com).]

For very broadband test applications, model ZFRSC-183+ is a two-way power splitter/combiner from Mini-Circuits (www.minicircuits.com) that supports use from DC to 18 GHz. It is coaxial, with SMA connectors, and achieves low typical insertion loss of 0.7 dB above the 6-dB power division.

Directional couplers, which allow tapping a small portion of a signal path for test purposes, are invaluable to assist with RF/microwave tests. They are available with extremely broad bandwidths from a number of different suppliers and with several different connector choices.

Krytar (www.krytar.com), to give one example, offers coaxial directional couplers in various frequency bands to 18 GHz, including the 16-dB model 1850 directional coupler with frequency range spanning 500 MHz to 18.5 GHz. It exhibits less than 1.1-dB insertion loss across its broad bandwidth and it can handle as much as 20 W average input power and as much as 3 kW input power for very short peaks. Standard connectors are SMA female, although Type-N female connectors are available as an option.

Anatech Electronics (www.anatechelectronics.com), which also makes directional couplers, may be better known for its RF/microwave filters, which allow the removal of unwanted interference and the isolation of desired signals in a test setup. The firm offers a number of different filter technologies featuring, for example, bandpass filters from 300 kHz to 20 GHz with 2 to 15 sections—as well as bandwidths from 1 to 100%—to serve a wide range of test-and-measurement filtering needs. The firm also offers an array of connectors with its filters, including SMA, Type-N, and BNC connector types.

MITEQ (www.miteq.com) provides many broadband components suitable for test-and-measurement applications, including directional couplers, mixers, phase shifters, terminations, and both solid-state and traveling-wave-tube (TWT) amplifiers for boosting test signal levels. As an example, model AMF-3F-26004000-33-8P is one of the firm's coaxial low-noise amplifiers (LNAs) with over 18-dB gain from 26 to 40 GHz. It has a maximum full-band noise figure of 3.3 dB, with a typical value of about 3.0 dB. The minimum output power at 1-dB compression is +8 dBm with typical output third-order intercept point of +16 dBm.

Another broadband amplifier supplier, RF-Lambda (www.rflambda.com), supplies power amplifiers and LNAs with manual and digital control interfaces. Many of are suitable for test applications through 40 GHz and supplied in coaxial and waveguide housings. An example of the LNAs is model RLNA20G40GA with 35-dB gain from 20 to 40 GHz. It is sup-

plied with 2.92-mm (K) connectors and achieves a 4.5-dB noise figure and +10-dBm output power at 1-dB compression.

M/A-COM Technology Solutions (www.macomtech.com) offers extensive lines of broadband active and passive components suitable for use in test-and-measurement applications. Product lines include digital attenuators, limiters, phase shifters, power detectors, and switches. Several different silicon- and GaAs-based semiconductor technologies account for switch products spanning DC to 70 GHz in a variety of different package styles, including coaxial packages suitable for use with test-and-measurement applications.

Narda Microwave East (www.narda-microwave.com), offers many lines of high-performance switching and passive component products suitable for use in test applications. Its model 2382-2 is a two-way power divider for use from 500 MHz to 6.0 GHz **(see figure)**. It handles as much as 250 W CW power.

When the need for testing is at millimeter-wave frequencies, Spacek Labs (www.spaceklabs.com) offers a range of components starting at 18 GHz. These include amplifiers, detectors, filters, frequency multipliers and converters, frequency sources, and mixers.

Spectrum Microwave's (www.spectrummicrowave.com) lines of broadband mixers, formerly Magnum Microwave, are available in versions with connectors and in surface-mount and drop-in packages from use from 0.5 to 26.5 GHz. The company targets many mixers for specific communications bands, but also offers broadband mixers for test-and-measurement applications. As an example, connector-housed mixers in the MM9xxG-40 series operate across RF and LO frequency ranges of 0.5 to 18.0 GHz and yield an IF range of DC to 300 MHz, making them ideal for broadband frequency translation of test signals.

Of course, many of the leading test-equipment manufacturers also supply broadband active and passive components in support of their instrumentation, and a visit to a favorite test-and-measurement website can usually reveal their available components. By way of example, Agilent Technologies (www.agilent.com) offers a wide variety of RF/microwave test components, such as the model 87405C preamplifier with 25-dB gain and ±1.5-dB gain flatness from 100 MHz to 18 GHz. The broadband amplifier features 6-dB noise figure from 0.1 to 4.0 GHz and 4.5-dB noise figure from 4 to 18 GHz with +15-dBm output power at 1-dB compression. MWRF

Editor's Note: To read an expanded version of this article, visit http://mwrf.com/active-components/components-aid-broadband-testing.

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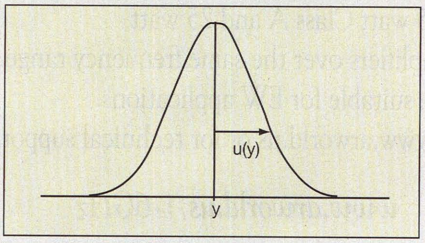
Understand Uncertainty FOR BETTER TEST ACCURACY

Measurement uncertainty is the bane of all designers, but understanding its sources—and the ways to reduce it—can provide assurance that designs meet their required performance.

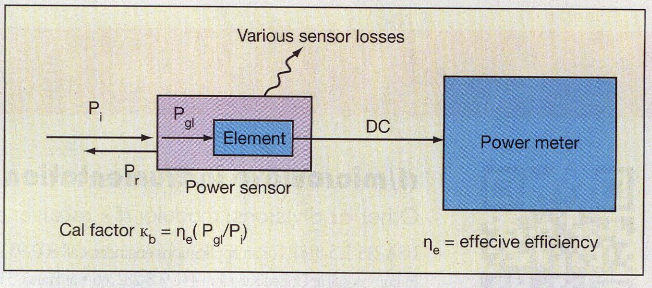
MEASUREMENT UNCERTAINTY impacts all instruments and measurements, no matter how well designed. Knowing more about the causes of measurement uncertainty and how to model it can provide greater confidence in the final results shown on an analyzer's or other RF/microwave instrument's display.

Designers typically apply a guard band around a performance parameter, such as insertion loss, to account for the difference between the acceptance test limit of the device under test (DUT) and the performance limit of the test equipment. The guard band can apply to measurement uncertainties as well as test-equipment performance variations due to drift over time, temperature, and other factors. Ideally, this guard band can be reduced as much as possible, although such a reduction requires a reliable estimation of measurement uncertainty. It must be done in a way that is relatively simple, fast, and conservative enough to inspire confidence in the measurement results.

Measurement uncertainty characterizes the dispersion of values below and above those obtained from a measurement, where "P" is the measured value and "u" is the measurement uncertainty. Total uncertainty is expressed as P ± u. Standard uncertainty is expressed as a standard deviation, u(y), as shown in **Fig. 1**, and relative un-



1. Standard uncertainty is expressed as a standard deviation, u(y). Relative uncertainty is standard uncertainty divided by the true value of the property being measured. Measurement uncertainty equals u(y) divided by "y".



2. The net power delivered to the sensor (P_{gl}) is the incident power (P_i) minus the reflected power (P_r). As not all of the input power is dissipated in the sensing element but rather is retained as heat, the actual measured power is just the value that the sensing element dissipates.

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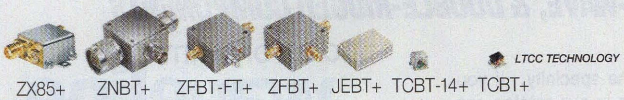
TCBT-6G+	50-6000	0.7	28	200	9.95
TCBT-14+	10-10,000	0.35	33	200	8.45
TCBT: LTCC, Actual Size .15" x .15", U.S. Patent 7,012,486.					
					Qty.1-9
JEBT-4R2G+	10-4200	0.6	40	500	39.95
JEBT-4R2GW+	0.1-4200	0.6	40	500	59.95
PBTC-1G+	10-1000	0.3	33	500	25.95
PBTC-3G+	10-3000	0.3	30	500	35.95
PBTC-1GW+	0.1-1000	0.3	33	500	35.95
PBTC-3GW+	0.1-3000	0.3	30	500	46.95
ZFBT-4R2G+	10-4200	0.6	40	500	59.95
ZFBT-6G+	10-6000	0.6	40	500	79.95
ZFBT-4R2GW+	0.1-4200	0.6	40	500	79.95
ZFBT-6GW+	0.1-6000	0.6	40	500	89.95
ZFBT-4R2G-FT+	10-4200	0.6	N/A	500	59.95
ZFBT-6G-FT+	10-6000	0.6	N/A	500	79.95
ZFBT-4R2GW-FT+	0.1-4200	0.6	N/A	500	79.95
ZFBT-6GW-FT+	0.1-6000	0.6	N/A	500	89.95
ZFBT-282-1.5A+	10-2800	0.6	45	1500	56.95
ZFBT-352-FT+	30-3500	0.4	23	4000	48.95
ZNBT-60-1W+	2.5-6000	0.6	45	500	82.95
ZX85-12G+	0.2-12000	0.6	N/A	400	99.95
ZX85: U.S. Patent 6,790,049.					

Note: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.



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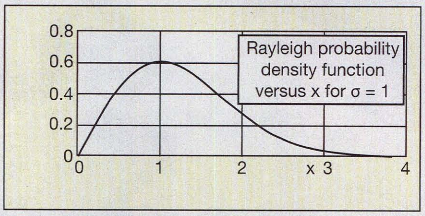
certainty is standard uncertainty divided by the true value of the property being measured. The true value of this property must be estimated, so measurement uncertainty equals u(y) divided by "y."

Mismatch uncertainty stems from incomplete knowledge of the phase of the reflection coefficients of the source and load impedances and their interconnection. It is defined as the amount of power (in dBm) unavailable at the output of a transmission line resulting from signal reflections and impedance mismatches. A transmission line that is properly terminated should suffer no reflections and, therefore, no mismatch loss.

Mismatch uncertainty is typically the greatest contributor to overall uncertainty from measurements made by power meters, signal analyzers, noise-figure meters, network analyzers, oscilloscopes, and signal generators, as well as test components such as attenuators, directional couplers, cables, and adapters. Mismatch uncertainty can be reduced by minimizing the reflection coefficient of transmission lines and components used within the test setup. The **table** offers methods for achieving this.

Instrument uncertainty differs with each type of instrument. It can stem from switching, drift of bandpass filters, calibration, and nonlinearities within the instrument. With a signal analyzer, for example, changes to its internal configuration should be minimized to reduce uncertainties. This can be achieved by stepping through a measurement before taking data. The analyzer should also run its alignment process and should be characterized using a calibration signal close to the frequency of interest.



3. The Rayleigh distribution model is accurate yet conservative, making it well suited for estimating mismatch uncertainty.

Power measurements can suffer a great deal of measurement uncertainty. There are many sources of uncertainty in these measurements, starting with the sensor and source impedance mismatch, followed by those from the power sensor and power meter. Referring to **Fig. 2**, P_{gl} represents the net power delivered to the sensor and is the incident power, P_i, minus the reflected power, P_r. However, not all of the input power is dissipated in the sensing element: Some is converted to heat in other parts of the sensor. The power registered on the meter is only that dissipated by the sensing element.

The calibration factor, K_b, accounts for the imperfect efficiency of the sensor and the mismatch loss and reflected signal, and is unique to each sensor. The calibration factor is printed on a power sensor's label or stored in an electronically erasable programmable read-only memory (EEPROM) for each sensor. A calibration sheet containing the unique calibration factor and reflection coefficient data is generally shipped with each sensor.

Components within a power meter contribute to measurement uncertainty and should be included in any uncertainty analysis, although the errors these components contribute are typically smaller than the source sensor mismatch and other sensor uncertainties. The most significant forms of power measurement uncertainty are power reference uncertainty and instrumentation uncertainty.

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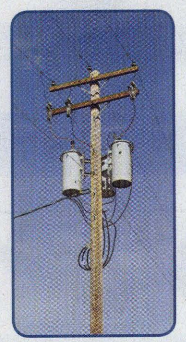
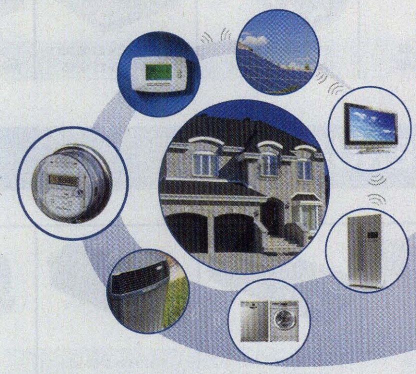
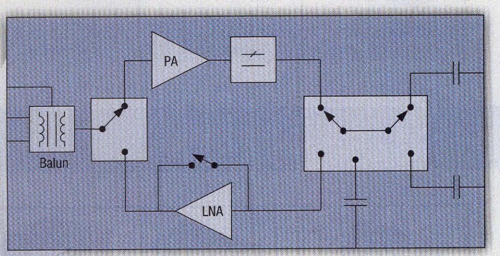


Neighborhood Area Network (NAN)



Home Area Network (HAN)



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Front-end Module (FEM) Block Diagram

Front-end Modules (FEMs)

Part Number	Function	P_{OUT} (dBm)	Tx Gain (dB)	Rx Gain (dB)	I_{CC} Tx (mA)	Package (mm)	Frequency Band (MHz) < 170	410–470	868–930	2400–2500
SKY66100	Tx / Rx Front-end Module with Rx / Tx Bypass	20–27	30	-0.5	110–300	MCM 4 x 4	•			
SKY65367-11	High Power Tx / Rx Front-end Module with Rx / Tx Bypass	30	35	-0.5	600	MCM 4 x 4	•			
SKY65338	Tx / Rx Front-end Module	27	32	–	315	MCM 8 x 8		•		
SKY65342-11	High Power Tx / Rx Front-end Module with Rx Bypass	29	34	-0.6	650	MCM 8 x 8		•		
SKY65378	Low Power Front-end Module with Tx Bypass and LNA	–	–	14–17	3–7[1]	QFN 4 x 4			•	
SKY65346-21	Tx / Rx Front-end Module with LNA	26	35	13.7	200	MCM 5 x 5			•	
SKY65313-21	Tx / Rx Front-end Module with LNA	30.5	28	16.6	695	MCM 6 x 6			•	
SKY65364	High Power Tx / Rx Front-end Module with LNA, PA, Tx / Rx Bypass, HD Filter	30.5	30	15	730	MCM 6 x 6			•	
SE2435L	High Power Tx / Rx Front-end Module with LNA	30	28	16	550	QFN 4 x 4			•	
SE2442L	High Power Tx / Rx Front-end Module with Rx Bypass	30	28	-0.7	550	QFN 4 x 4			•	
SE2438T	Low Power Tx / Rx Front-end Module with LNA	10–14	16	12.3	20–33	QFN 3 x 3				•
SE2431L	Tx / Rx Front-end Module with LNA	20	23	12	110	QFN 3 x 4				•
SE2432L	Tx / Rx Front-end Module with LNA	20	22	11.5	110	QFN 3 x 4				•
SE2436L	High Power Tx / Rx Front-end Module with LNA	27	28	11.5	400	QFN 4 x 4				•

1. SKY65378: I_{CC} Rx gain value shown.

Power Amplifiers

Part Number	Function	P_{OUT} (dBm)	Gain (dB)	$P_{1\,dB}$ (dBm)	Package (mm)	Frequency Band (MHz) 450	915	2400
SE2433T	2-Stage Power Amplifier	24	22	24	QFN 2.5 x 2			•

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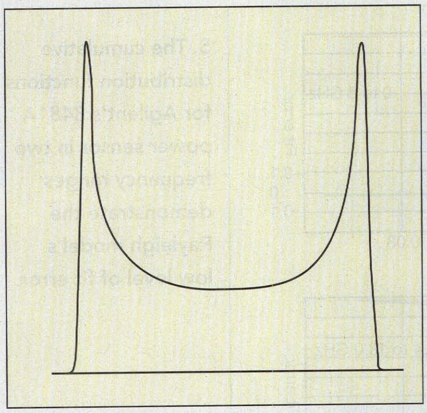


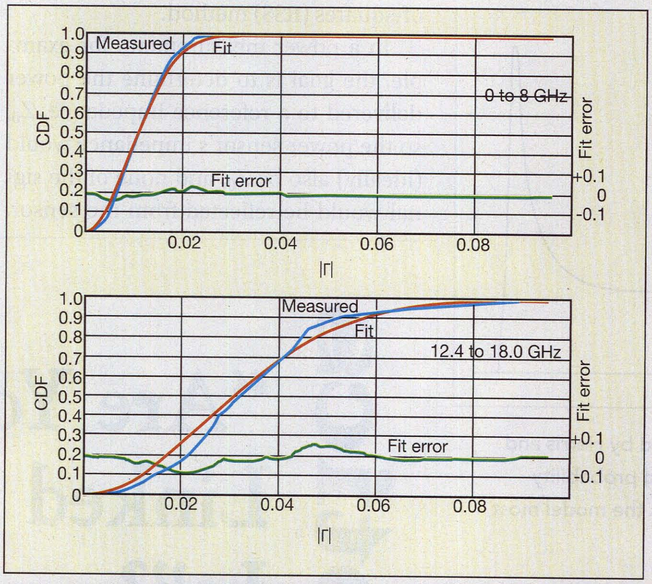
4. The model described by Harris and Warner has a U-shaped probability density function and is the model most widely used.

For power reference uncertainty, thermocouple and diode sensors require a highly accurate, known power source to verify and adjust for the sensitivity of the individual sensor.

Power meters from Agilent Technologies (www.agilent.com), for example, employ a 1-mW (0-dBm), 50-MHz calibration source as a reference. Power reference uncertainty refers to the uncertainty in the output level of this calibration source, which is specified for Agilent's calibration sources as ±0.6% for 2 yr. at +25 ± 10°C. Instrument uncertainty is the combination of meter tracking, circuit nonlinearities, and amplifier gain uncertainties, and a manufacturer guarantees the accumulated uncertainty will be within a specific limit, such as ±0.5% for absolute average power measurements.

Determining total measurement uncertainty requires that all major sources of uncertainty be considered; once these have been identified, the uncertainties from each source can be estimated. Total measurement uncertainty is obtained by adding the uncertainties from each source. This is a conservative approach, and necessary if it cannot be determined whether the individual sources of uncertainty are independent of each other. If it can be determined these individual sources of uncertainty are independent, they can be added using the root-sum-of-squares (RSS) method.

In a power measurement, for example, the goal is to determine the power delivered to a reference impedance, Z_0, so the power sensor's impedance would (ideally) also be Z_0, and none of the signal would be reflected from the sensor. When the sensor impedance deviates from Z_0, it represents a mismatch with the power source and reflections occur, with some source power failing to reach the sensing element; this makes a totally accurate measurement impossible. Since the source is typically mismatched,



5. The cumulative distribution functions for Agilent's 8481A power sensor in two frequency ranges demonstrate the Rayleigh model's low level of fit error.

Techniques for reducing mismatch uncertainty

Minimize cable length	At 300 MHz and below, transmission lines should be as short as possible to reduce the change of phase with frequency. Although this applies to higher frequencies as well, it is not as effective at higher frequencies where even short cable lengths are significant fractions of a wavelength.
Reduce the number of adapters	While these components are often necessary, they should be used sparingly and cannot be stacked.
Use the same connector type throughout the setup	APC-3.5 and SMA connectors, for example, may look similar but have different mechanical interfaces. If necessary, a precision adapter, or "connection saver," is recommended between them.
Use a torque wrench	Not only does this prevent over- or under-tightening connectors, it ensures there will be little tightness variation when another operator takes over.
Characterization and care of cables, connectors, and adapters	Using a network analyzer, record the results for comparison at the next regular test station audit. Keep precision connectors clean and gauge them regularly. Connectors are gauged by measuring it with a dial gauge to ensure it has not been damaged, which will destroy any part it mates with.
Use an attenuator to reduce VSWR	Place the attenuator at one end of the transmission line (preferably the line with the lowest return loss) to improve flatness. Note that this assumes its return loss is greater than the original source or load. The output of the signal generator may need to be increased to maintain the proper signal level at the load.
Use an isolator to reduce load reflections	These components are more expensive than attenuators, but are justifiable at high power levels when the power lost in an attenuator would be high, as well as at very low power levels when the signal would be masked by thermal noise.
Use a power splitter	A leveling loop creates a Z_0 impedance at the center point of the splitter so the resulting "generator output impedance" equals the well-matched microwave resistor in the second arm of the splitter. The leveling loop uses low-frequency feedback to improve the effective source match to the line and requires a two-resistor power splitter or a directional coupler. The output of the signal generator is measured with a power meter and adjusted so indicated power is at the required level.

reflections will also occur at that point. Phase addition and subtraction of the incident and reflected waves create a voltage standing wave pattern on the transmission line and, although the exact power entering the sensor cannot be determined, the maximum and minimum power values can be calculated from the VSWR of the source and sensor.

When measuring the performance of RF and microwave subsystems and systems, correcting for mismatch with a high level of certainty requires knowledge of source and load reflection coefficients. Unfortunately, in many measurement situations only the reflection coefficient magnitude is known. Without the required phase information, it is impossible to accurately correct for a mismatch, which will then represent a source of error in a power measurement.

When phase is not known, there are three models available for assessing uncertainties: one well suited for determining mismatch uncertainty using measured values of reflection coefficient magnitude, another relying on Rayleigh distributed values when reflection coefficient magnitude must be assumed, and the third combining measured and assumed values. Of the three, the Rayleigh distribution model **(Fig. 3)** has greater utility and has been shown to provide a more accurate assessment of uncertainty.

However, it is not as widely used as the technique described in ref. 1, which is based on the uncertainty of having a U-shaped distribution **(Fig. 4)** and assumes that reflection coefficient magnitudes always reflect the maximum amount stated on a manufacturer's data sheet. The U-shaped probability distribution provides only one-half of the required information as total mismatch uncertainty requires knowledge of errors associated with the magnitude of reflection coefficient.

Total uncertainty can be determined by estimation and an associated uncertainty, or by assigning a probability density function (PDF) to the reflection coefficient magnitude. Assigning a PDF to reflection coefficient magnitude can be used when data is available from the instrument manufacturer's data sheet, although each manufacturer states distribution of reflection coefficient magnitude differently. For example, power sensors, signal generators, and signal analyzers from Agilent Technologies feature guaranteed VSWR specifications; the company's latest power sensors include a graph of typical VSWR versus frequency as well.

The model of ref. 1, known as the Harris and Warner model, accounts for the error associated with measured val-

ues of reflection-coefficient magnitude as well as the error caused by unknown phase. When it is necessary to assume reflection-coefficient magnitude values, the Rayleigh distribution gives the most accurate estimate of uncertainty. Investigations have shown that the Rayleigh model—when evaluated on power sensors, signal generators, and signal analyzers—provides results much closer to "reality" than other methods.

Since the Rayleigh model depends on a large number of reflective elements, it could be assumed that power sensors, the least complex of the three instruments studied, might not fit well with a Rayleigh distribution. In fact, the Rayleigh model is a good fit for power sensors and power measurements. **Figure 5** compares the measured reflection-coefficient magnitude with a best-fit model from DC to 8 GHz and 12.4 to 18 GHz. The fit in the DC-to-8-GHz region is very close, with a good fit even at higher frequencies exhibiting variations in mean VSWR.

The accuracy of the Rayleigh model is apparent upon comparison with results from other models. With the popular U-shaped distribution equivalent to a known maximum reflection coefficient with uniformly distributed phase, the example of an Agilent model 8481A power sensor between 12.4 and 18 GHz shows a VSWR of 1.28:1 and a reflection coefficient of 0.123. The observed statistical distribution of reflection coefficient in the lower plot of higher frequencies in **Fig. 5** shows no probability higher than 0.090, and only minor variations from a Rayleigh model with reflection coefficient between 0.01 and 0.08. The Rayleigh model is clearly much more accurate, even at its worst, than using the data-sheet specification.

The estimated uncertainty is roughly proportional to the median of the distribution function. The Rayleigh model achieves high accuracy by using the mean reflection coefficient. In fact, it usually provides a six times lower estimate of uncertainty than the U-shaped distribution approach. It is also conservative enough to allow a designer to reduce a guard band with confidence. In short, the Rayleigh model provides a fast, accurate estimate of standard uncertainty caused to mismatch and can help improve confidence in a variety of RF/microwave measurements. MWRF

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FOOTNOTE

1. Agilent Application Note 1449-3, "Fundamentals of RF and Microwave Power Measurements," documents these practices. Along with the companion Average Power Sensor Uncertainty Calculator, it is available at www.agilent.com.

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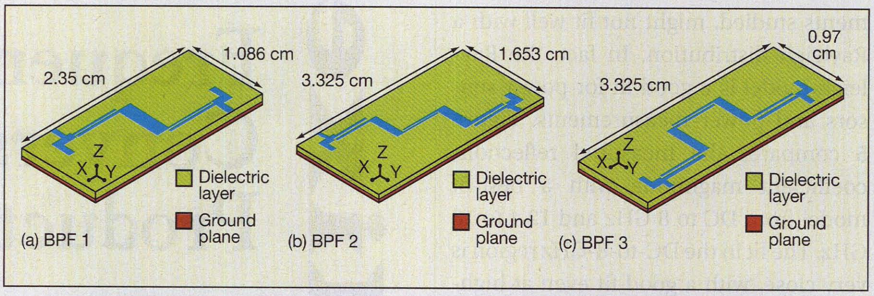
Wide Filter Stopband Aids UWB Systems

Based on a multiple-mode resonator, this compact ultrawideband bandpass filter has low passband loss from 3.1 to 10.6 GHz with high rejection in the upper stopband.

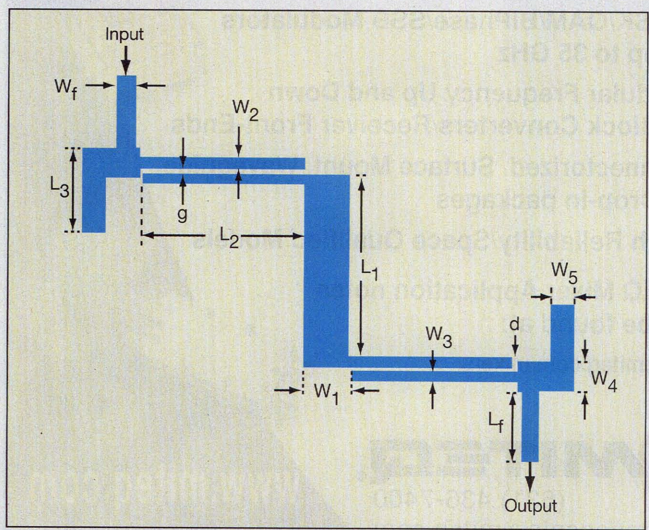
ULTRAWIDEBAND (UWB) communication systems offer great promise for transferring high-speed data, provided that proper filtering can be achieved to prevent interference. Since the Federal Communications Commission (FCC) established the UWB spectrum for commercial use in 2002,[1] various UWB system topologies have been developed for use from 3.1 to 10.6 GHz, with a corresponding need for UWB bandpass filters. In late 2003, the first UWB filter was documented, using microstrip ring resonators with loaded open stubs to achieve dual stopbands.[2]



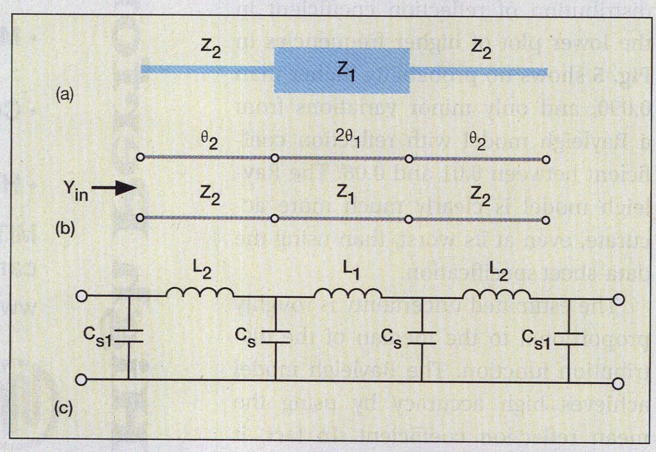
1. These three layouts show the topologies of the three UWB bandpass filters: (a) one-pole BPF 1, (b) two-pole BPF 2, and (c) folded two-pole BPF.

The use of multiple-mode resonators (MMRs) has supported a new generation of UWB filters. For example, refs. 3 and 4 detail a stepped-impedance MMR with half-wavelength λ/2 low-impedance segments at the center and two identical quarter-wavelength λ/4 high-impedance segments at both sides, which allocated its three resonant modes within the UWB frequency range. Subsequently, an UWB bandpass filter was proposed with nonuniform coplanar-waveguide (CPW) MMR with short-circuited ends.[5]

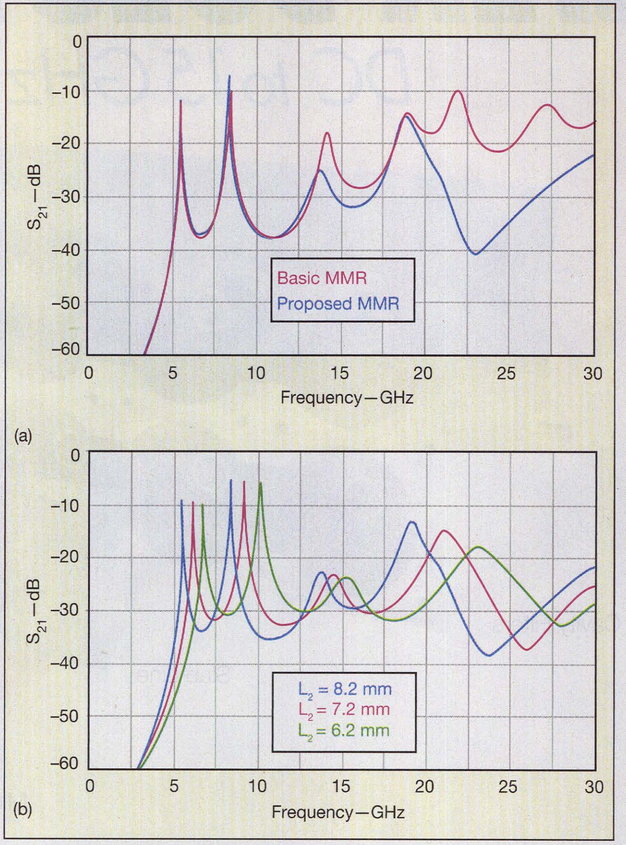
Another UWB filter was realized by loading three open stubs in parallel with a conventional MMR resonator in the center and two symmetrical locations, respectively.[6] This approach exploits the first four resonant modes of the MMR for relocation within the UWB frequency range while pushing up the fifth resonant mode to create a wider upper stopband. Also, electromagnetic-



2. This layout shows the structural parameters for the proposed UWB BPF.



3. This schematic diagram of the stepped-impedance MMR (a) is shown besides its equivalent-circuit model (b) and its LC equivalent-circuit model (c).



4. These plots show (a) the simulated S_{21} responses of the proposed and basic MMRs, and (b) the simulated S_{21} responses for the proposed MMRs with different values of L_2.

bandgap (EBG) embedded MMRs were applied to the design of UWB filters for improved upper stopband performance.[7] In addition, by attaching three pairs of circular impedance-stepped stubs in parallel to a high-impedance microstrip line, an MMR capable of supporting a wide passband and stopband was developed.[8] Similarly, the use of a spiral-shaped loaded multiple-mode resonator also shrinks the size of a wideband bandpass filter circuit while enhancing its bandwidth.[9] The current author has proposed numerous filter topologies based on folded stepped-impedance resonators (FSIRs) with parallel high-impedance segments to achieve a compact notched UWB bandpass filter and an UWB lowpass filter with wide stopband.[10-12] In the present report, a compact UWB bandpass filter structure was developed. It consists of folded multiple-mode resonators coupled to each other and to SIRs using a parallel coupled configuration; the feedlines are tapped off the SIRs. The proposed filter features a wide passband response from 3.1 to 10.6 GHz that meets the FCC's limits for handheld and indoor UWB communications devices. In addition, it exhibits an extremely wideband stopband with 20-dB rejection extending to U-band frequencies for suppression of unwanted signal content outside of the FCC UWB comunications range. By using transmission zeros produced by tapped parallel-coupled lines, higher-order resonant modes, due to the harmonic nature of a stepped-impedance MMR resonator, can be sufficiently quelled to create the broad stopband exhibited by this bandpass filter.

Figures 1(a), (b), and (c) show three UWB filter topologies (named BPF 1, BPF 2, and BPF 3, respectively). The design in **Fig. 1(a)** uses an MMR which is coupled to the SIRs by means of a parallel coupled configuration. The folded MMR has resonance characteristics similar to those of a stepped-impedance MMR, although the folded MMR contributes to both size reduction and upper-stopband improvement. The filter was designed and fabricated on RT/duroid® 5880 circuit material from Rogers Corp. (www.rogerscorp.com) with relative permittivity (dielectric constant) of 2.20 at 10 GHz through the z-axis (thickness) of the material, thickness of 1.52 mm, and loss tangent (dissipation factor) of 0.0009.

Figure 2 illustrates the layout of the proposed UWB BPF with its structural parameters. **Figures 3(a), (b), and (c)** show the geometry, equivalent-circuit model, and inductive-capacitive (LC) equivalent-circuit model of the basic open-circuited stepped-impedance MMR. It consists of a

Comparing UWB bandpass filter designs

Reference	Size (λg^2)	Passband width (GHz)	Insertion loss (dB)	Return loss (dB)	20-dB upper stopband (GHz)	Structure
3	1.02 × 0.15	2.96 ~ 10.67	0.55	10.0	1.0	MMR + parallel coupled lines
4	2.07 × 0.08	Not mentioned	1.30	14.0	4.1	MMR + interdigital coupled lines
6	1.03 × 0.22	2.80 ~ 10.27	0.80	14.3	4.0	MMR + interdigital coupled lines
8	1.02 × 0.19	2.80 ~ 10.20	1.00	10.0	15.7	MMR + interdigital coupled lines
Current design	0.79 × 0.36	3.10 ~ 10.60	0.28	12.2	49	MMR + parallel tapped coupled lines

low-impedance line section in the middle with characteristic impedance represented by Z_1 and electrical length θ_1, along with two identical high-impedance line sections with characteristic impedance Z_2 and electrical length θ_2 on both sides. The input admittance (Y_{in}), viewed from the open end of the filter structure, can be derived from Eq. 1:

$$Y_{in} = jY_2\ 2(R\tan\theta_1 + \tan\theta_2)(R - \tan\theta_1\tan\theta_2)\ /R(1 - \tan^2\theta_1)(1 - \tan^2\theta_2) - 2(1 + R^2)(\tan\theta_1\ \tan\theta_2) \qquad (1)$$

The resonance condition for this UWB bandpass filter design can be derived from the following:

$$Y_{in} = 0 \qquad (2)$$

The fundamental and higher-order-mode resonances occur alternately in the odd and even modes and can be obtained from electrical lengths θ_1 and θ_2 by the following two transcendental equations:

for the odd mode:

$$R - \tan\theta_1\tan\theta_2 = 0 \qquad (3)$$

for the even mode:

$$R\tan\theta_1 + \tan\theta_2 = 0 \qquad (4)$$

By choosing $\theta_1 + \theta_2 = 2\theta$ and streamlining the design equation, the following can be derived from Eq. 1:

$$Y_{in} = jY_2\ 2(1+R)(R - \tan^2\theta)(\tan\theta)\ /R - 2(1 + R + R^2)(\tan^2\theta) + R\tan^4\theta \qquad (5)$$

where $R_z = Z_2/Z_1$ is the impedance ratio of the stepped-impedance MMR. With the fundamental and higher-order-mode resonances represented by f_{m1}, f_{m2}, f_{m3}, and f_{m4}, with corresponding electrical lengths of θ_1, θ_2, θ_3, and θ_4, it is possible to obtain the following using Eqs. 1 and 2:

$$\tan^2\theta_1 - R = 0 \text{ or } \theta_1 = \arctan\sqrt{R},$$

$$\tan^2\theta_2 = \infty \text{ or } \theta_2 = \pi/2,$$

$$\tan^2\theta_3 - R = 0 \text{ or } \theta_3 = \pi - \arctan\tan\sqrt{R},$$

$$\tan^2 \theta_4 = 0 \text{ or } \theta_4 = \pi. \quad (6)$$

Thus:

$$f_{m2}/f_{m1} = \theta_2/\theta_1 = \pi/2\arctan\sqrt{R},$$

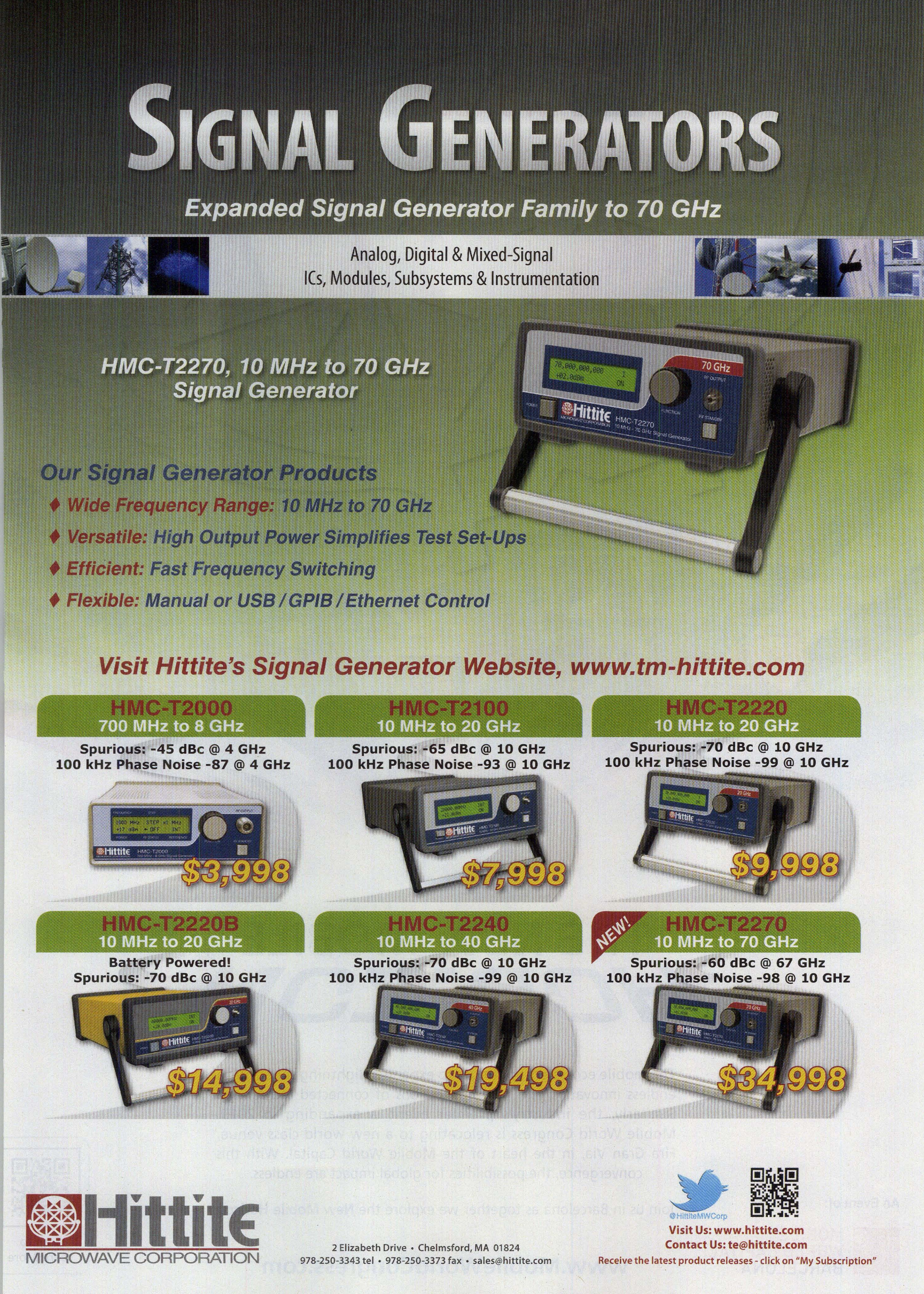
$$f_{m3}/f_{m1} = \theta_3/\theta_1 = (\pi/\arctan\sqrt{R}) - 1,$$

$$f_{m4}/f_{m1} = \theta_4/\theta_1 = (\pi/\arctan\sqrt{R}). \quad (7)$$

In the filter design, the impedance ratio and first resonant mode are set by means of $R_z = 2.05$ and $f_{m1} = 5.65$ GHz. From Eq. 5, the frequency ratios f_{m2}/f_{m1}, f_{m3}/f_{m1}, and f_{m4}/f_{m1} can be selected nearly as 1.6, 2.3, and 3.3, respectively. Once R_z is determined, the high-impedance segments of the MMR can be folded to achieve a more compact design. **Figure 4(a)** shows simulated frequency-response curves for the basic and folded MMRs under weak capacitive coupling. The resonators have similar behavior—with four resonant modes distributed around 5.61, 8.44, 13.57, and 18.85 GHz—validating the theoretical analysis. The folded MMR is capable of yielding transmission zeros at higher frequencies, contributing to good upper-stopband performance.

Several degrees of freedom exist for adjusting the location of the resonant modes. **Figure 4(b)** shows the simulated forward-transmission (S_{21}) response of the proposed MMRs with different values of length L_2. From **Fig. 4(b)**, as L_2 increases, the resonances shift lower in frequency. For tighter coupling between input and output resonators using the proposed MMR designs, the parallel-coupled structure of **Fig. 5(a)** was used. This feed structure is composed of two FSIRs that are capacitively coupled, and the I/O lines are tapped off the SIRs as shown. Capacitive coupled structures or parallel-coupled lines have been widely evaluated in multistage wideband filters because of their simple design procedure.[13] The drawback to this approach is its practical limitations. For wideband filters, the space between the coupled lines must be minimized for tight coupling, and it is difficult to realize such small gap spacing in typical manufacturing processes.

The proposed feed structure offers ad-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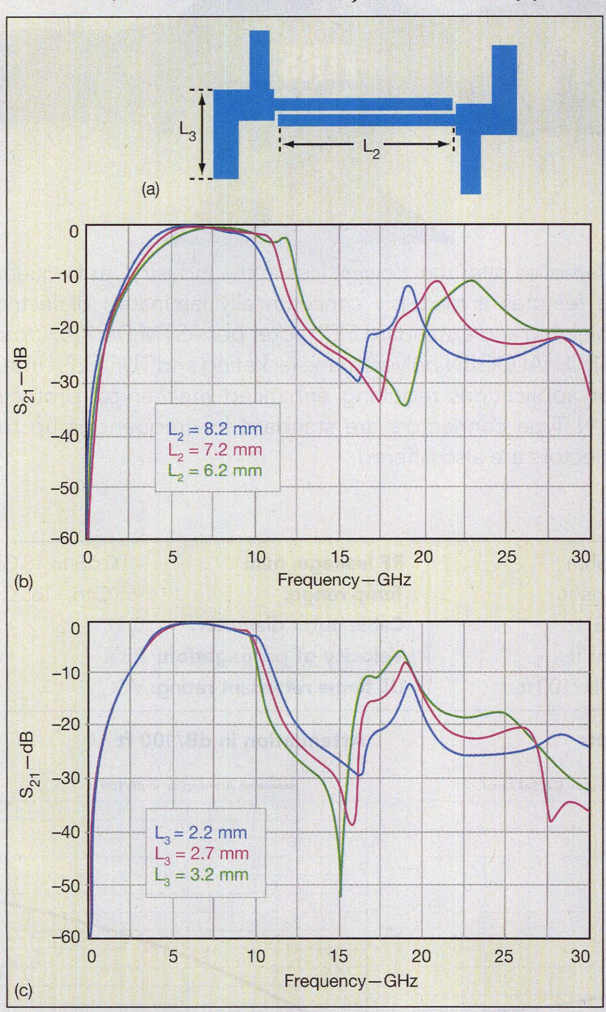
vantages over conventional approaches, including a wider and sharper stopband region. A tapped-line I/O structure is part of this approach. Also, since the first and last portions of the filter have been eliminated, a design with tapped I/O ports can save space on a printed-circuit-board (PCB) design. The position of the tapped-line I/O port is optimized for higher rejection in the stopband. To better understand the impact of different feed parameters on the frequency response of the feed structure, simulated S-parameters were calculated for different dimensions of L_2 and L_3 as shown in **Figs. 5(b) and (c)**, respectively. One transmission zero is located at about 16.09 GHz, but its location and rejection level can be adjusted by changing the values of L_2 and L_3.

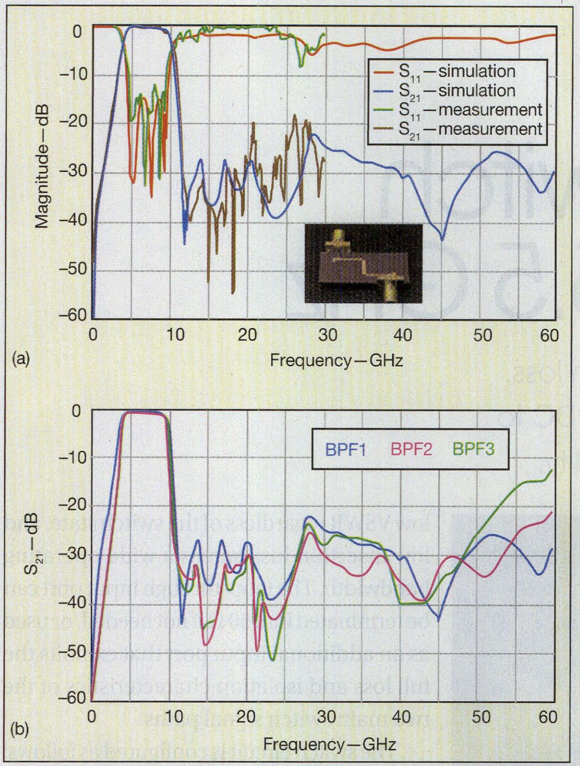
As can be seen from **Fig. 5(b)**, when L_2 decreases from 8.2 to 6.2 mm in 1-mm steps, and the other parameters remain fixed, the coupling transmission zero will move higher in frequency. From **Fig. 5(c)**, it is obvious that by increasing L_3 from 2.2 to 3.2 mm in 0.5-mm steps, the coupling zero will decrease in frequency with a deeper rejection level.

With the above-described features, it is feasible to control the resonant modes of the proposed resonator and transmission zeros of the designed coupling structure by tuning their structural parameters. **Figure 6(a)** shows full-wave simulated and measured S-parameter responses for the proposed UWB bandpass filter, where the physical dimensions are $L_f = 1$ mm, $L_1 = 6.7$ mm, $L_2 = 8.2$ mm, $L_3 = 2.2$ mm, $W_f = 1.0$ mm, $W_1 = 1.6$ mm, $W_2 = 0.2$ mm, $W_3 = 0.7$ mm, $W_4 = 1.4$ mm, $W_5 = 1$ mm, $g = 0.13$ mm, and $d = 0.1$ mm. Obviously, **Fig. 6(a)** shows that the filter's 10-dB passband effectively spans 3.1 to 10.6 GHz.

The new filter topology has several advantages over the conventional MMR-based UWB bandpass filter of ref. 3, including higher passband return loss, a sharper response, and wider stopband. The **table** compares the current design with a number of previously reported UWB bandpass filters. To improve the out-of-band performance in both the lower and upper stopbands of the current design, another MMR could be coupled with the first MMR via coupled lines, as shown in **Figs. 1(b) and (c)**. Simulated S-parameters for these respective filter



5. The schematic diagram of (a) the proposed coupling structure is shown next to (b) the simulated S_{21} responses for the proposed coupling structure with different values of L_2 and (c) simulated S_{21} responses for the proposed coupling structure with different values of L_3.



6. These plots show (a) the simulated and measured S-parameter responses as functions of frequency for the proposed UWB bandpass filter design, accompanied by a photograph of the fabricated filter as fabricated on commercial low-loss PCB material with relative dielectric constant of 2.20 and (b) a comparison of S-parameter responses for filters BPF 1, BPF 2, and BPF 3.

designs (BPF 2 and BPF 3) are shown in **Fig. 6(b)** for comparison with the original design, BPF 1. In a case where compact size is required, BPF 1 is more appropriate. But for an application requiring a sharper response and higher rejection level in the stopband, both BPF 1 and BPF 2 are useful. However, BPF 3 offers a more compact size.

In summary, the new bandpass filter design is well suited for isolating UWB communications signals from surrounding interference and competing communications systems. It features a wide upper stopband and low insertion loss throughout the passband of 3.1 to 10.6 GHz, with no more than 0.28-dB loss ripple for outstanding amplitude performance. The return loss across its wide passband is better than 12.26 dB and the stopband rejection is better than 20 dB at frequencies well beyond the UWB passband. The bandpass filter is quite small—in terms of wavelength it is approximately $0.79\lambda_g \times 0.36\lambda_g$—where λ_g is the guided wavelength at 6.85 GHz. MWRF

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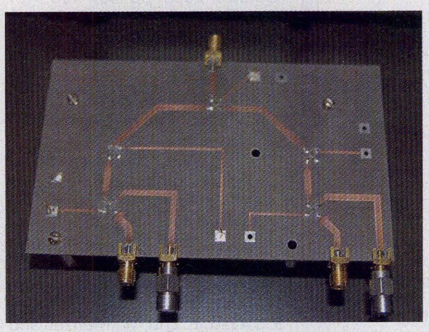
Dual-Channel Switch Controls DC To 5.5 GHz

This dual-channel switch circuit provides low insertion loss, high isolation, and excellent transient response from DC to 5.5 GHz, with two loop-through ports that add versatility.

BROADBAND RF/MICROWAVE switches are invaluable as signal control elements in many systems, especially when they can minimize loss and maximize isolation between ports. But a dual-channel, broadband switch with a loop-through port provides even greater versatility, since the additional switched port can be terminated in 50 Ω or used for such functions as signal sampling. The switch described here features a bandwidth of DC to 5.5 GHz and approximate risetime of 47 ps.



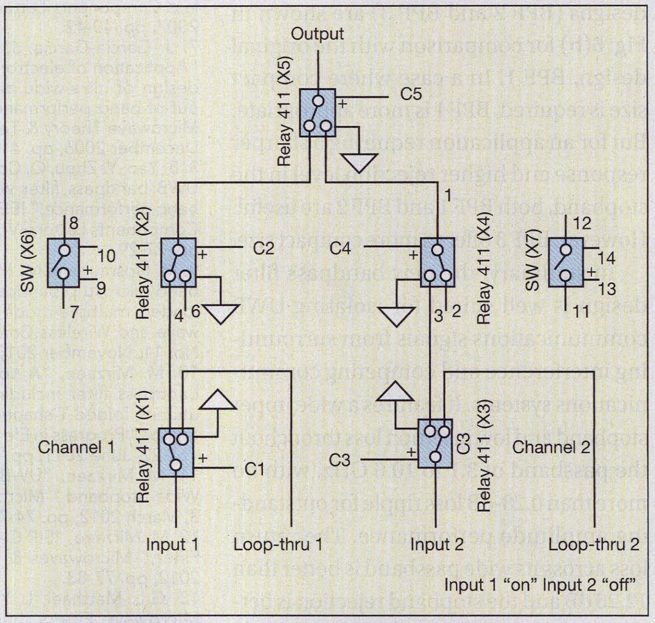
1. This is one possible circuit layout for the switch, fabricated on RT/duroid 5870 PCB material.

The new five-port switch builds upon RF electromechanical relay technology, incorporating a pair of relays to control the two switch channels. For comparison purposes, a typical circuit with a single relay might achieve as much as 45 dB isolation at 100 MHz and 25 dB isolation at 1 GHz. The single relay also exhibits insertion loss of approximately 0.1 dB at 100 MHz and 0.4 dB at 1 GHz. In contrast, the two-channel switch delivers more than 140 dB isolation at 100 MHz and better than 90 dB isolation at 1 GHz. The penalty in insertion loss is only 0.14 dB at 100 MHz and 0.63 dB at 800 MHz.

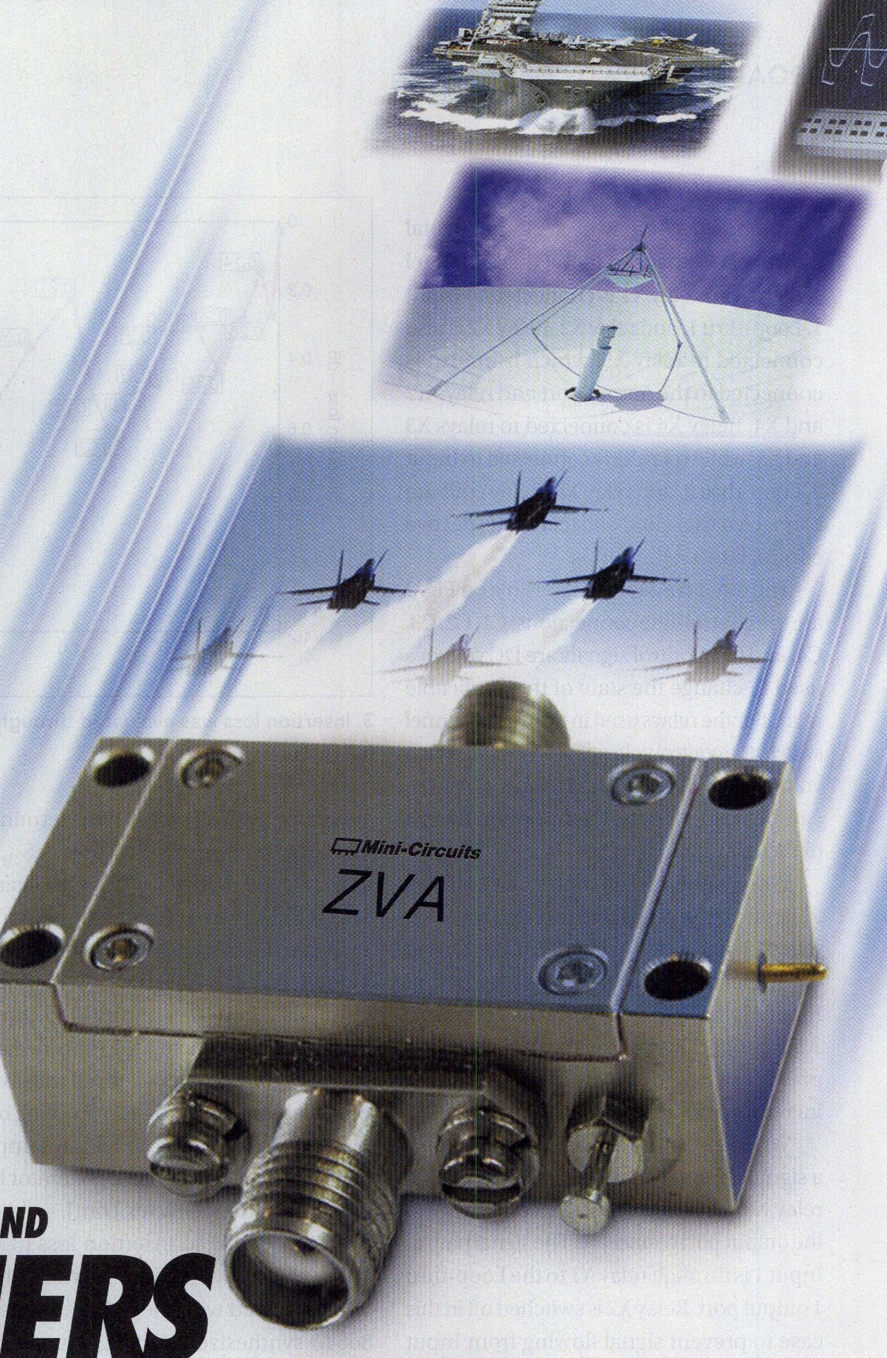
A prototype of the dual-channel switch circuit **(Fig. 1)** was constructed on 31-mil-thick RT/duroid® 5870 printed-circuit-board (PCB) material from Rogers Corp. (www.rogerscorp.com). It is a glass-microfiber-reinforced polytetrafluoroethylene (PTFE) composite material with dielectric constant of 2.33 in the z-axis at 10 GHz, and low dissipation factor of 0.012 in the z-axis at the same frequency. The RT/duroid 5870 board was reinforced for structural stability through the attachment of a 62-mil-thick FR-4 PCB.

The switch improves upon switching circuit designs employing high-frequency relays. It offers increased bandwidth compared to a single-relay circuit, due to the use of microstrip distributed filters. These filters are fabricated in the form of tapered and nontapered microstrip transmission lines. The dual-relay switch achieves performance levels not possible in single-relay designs, like the high isolation between channels, 50-Ω impedance at all ports with low VSWR regardless of the switch state, and low insertion loss across a wide operating bandwidth. The loop-through input port can be terminated into 50 Ω if not needed, or used as an additional input port that exhibits the full loss and isolation characteristics of the two main switch signal paths.

The switch circuit is configured as follows: Channel 1 consists of an input port (Input 1), an output port (Output), and a loop-through port (Loop-thru 1) which can connect to the input or output port. Channel 2 has its own input port (Input 2), the same output port (Output), and a loop-through port (Loop-thru 2) which can also connect to the input or output port. The loop-through inputs as inputs for additional switches or as additional inputs for a system using the dual-channel switch.



2. This schematic diagram shows the basic architecture of the loop-through switch.



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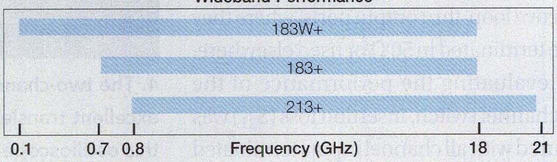

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440 rev M

From **Fig. 2**, it may be seen that a total of five relays are used in the dual-channel switch, with relay X1 is connected to Input 1, Loop-thru 1, and relay X2. Relay X2 is also connected to relay X5, which is in turn is connected to the output port and relays X2 and X4. Relay X4 is connected to relays X3 and X5, while relay X3 is connected to Input 2, Loop-thru 2, and relay X4. Relay coils are connected to ground and to their respective control lines.

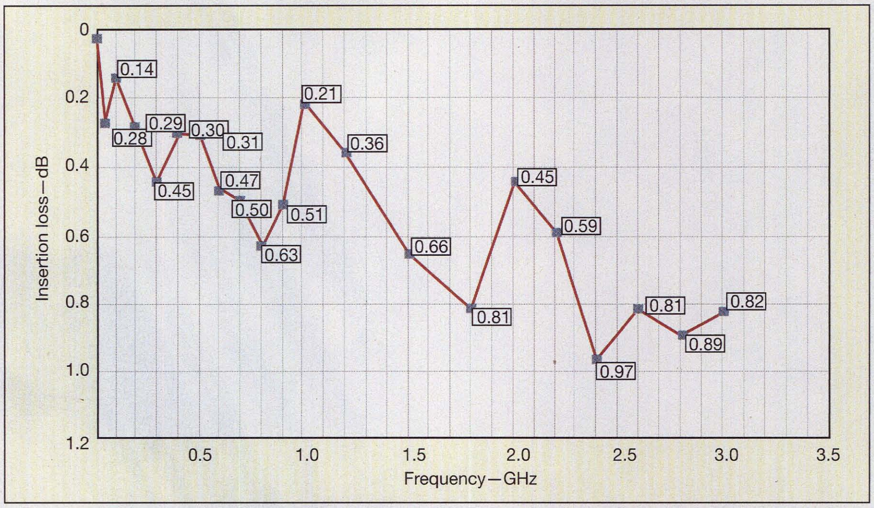
The other contact points visible on **Fig. 2** are the control-line connections: C1, C2, C3, C4, and C5. Control signals are DC voltages used to change the state of the applicable relay. For the relays used in the dual-channel switch, the control voltage is +5 VDC, although voltages of +6, +9, +12, +18, and +24 VDC can be used, depending upon the design of the relay coil.

When Input 1 is "on" and Input 2 is "off," a signal at Input 1 passes through relay X1, relay X2, and output relay X5 on its way to the output port connector. The signal path at Input 2 is through relay X3 to the Loop-thru 2 output port. Relay X4 is switched "off" to prevent signal flowing from Input 2 and to increase the channel isolation.

When Input 2 is "on" and Input 1 is "off," a signal at Input 2 passes through relay X3, relay X4, and output relay X5 on its way to the output port connector. The signal path at Input 1 is through relay X1 to the Loop-thru 1 output port. Relay X2 is switched off in this case to prevent signal flowing from Input 1 and to increase channel isolation. In the two-channel switch circuit, relays X2 and X4 are three-port components with an unused port for each. But it is also possible to use two-port relays without the unused ports.

Unlike a traditional two-channel switch, Input 1 and Input 2 can both be switched "off" at the same time. When this is done, both input signals will be available at their respective loop-thru output ports, where they can be terminated in 50 Ω or used elsewhere.

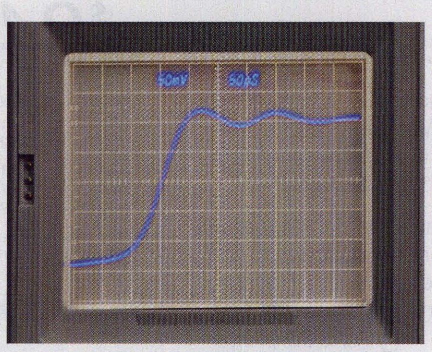
In evaluating the performance of the dual-channel switch, insertion loss (S_{21}) was measured with all channel inputs terminated into 50 Ω and all loop-through outputs terminated into 50 Ω. The frequency response was measured as the ratio of the output voltage to the input voltage measured by the signal generator, with all switch ports terminated into 50 Ω. Isolation was measured as S_{21}, with the input port switched off for each channel. This is the input to output port isolation.



3. Insertion loss was evaluated through 3 GHz with level response across the full frequency range.

Return loss was measured with all channel inputs terminated into 50 Ω, the output port terminated into 50 Ω, and all loop-through outputs terminated into 50 Ω. The two-channel switch circuit was characterized with a commercial high-speed digital sampling oscilloscope (DSO), with model S-6 sampling head and model S-52 pulse generator head from Tektronix (www.tek.com).

The broadband insertion loss (3-GHz scan) of the two-channel switch circuit was measured with the aid of a model HP 8664A synthesized signal generator from Hewlett-Packard Co. (now Agilent Technologies; www.agilent.com). Two measurements were made at each frequency: one with the 2 Channel Switch removed from the signal path, and the second with the 2 Channel Switch in the signal path. The loss in dB was then calculated. The plot shows a response of –0.05 to –0.97 dB over a frequency range of 10 MHz to 3 GHz **(Fig. 3)**.



4. The two-channel switch circuit boasts excellent transient response, as shown by this oscilloscope display. The test signal source is a Tektronix S-52 pulse generator head with rise time of better than 25 ps, and the S-6 sampling head has a rise time of better than 30 ps.

The return loss of the two-channel switch was measured with a model SP2369 autotester from Wiltron (now Anritsu; www.anritsu.com) from 2 to 12 GHz. The VSWR across this frequency range is 2.0:1 or better whether the input port is active or not. Computer simulations of the switch circuit's S_{11} behavior with the input port switch in the "off" position indicate that return loss is better than 40 dB at the lowest frequencies, rising to about 12 dB at 5.6 GHz.

The risetime of the switch **(Fig. 4)** was determined by subtracting the risetime of the measurement system without the switch in place from the measured risetime of the same measurement system with the switch circuit under test. The formula is simply: $[(\text{measured risetime})^2 - (\text{system risetime})^2]^{0.5}$ The system in this case is the S-52 pulse generator head, the S-6 sampling head, and the interconnect cables. This system exhibits a risetime of 37 ps. The measured risetime with the two-channel switch in place is 60 ps. Finally, the square root of the sum of the squares of these two values yields a calculated risetime of 47 ps for the switch alone. MWRF

Conquer Testing Of IEEE 802.11ac MIMO

THE IEEE 802.11AC wireless-local-area-network (WLAN) standard features multiple-input multiple-output (MIMO) support with up to eight spatial streams, despite the fact that only one is mandatory. In a five-page application note titled "Solutions for Design and Test of 802.11ac MIMO," Agilent Technologies delves into the design and test challenges posed by MIMO and how they can be handled. MIMO's complexity creates challenges for the IEEE 802.11ac system engineer—especially when it comes to RF transmitter design. An IEEE 802.11ac system's MIMO performance can be degraded by MIMO spatial multiplexing algorithms, multiple transmit/receive RF chains, multiple antennas, and system-level impairments. Among other issues is the need to establish RF transmitter performance required for 256QAM operation as well as the local-oscillator (LO) phase-noise performance needed to meet an error-vector-magnitude (EVM) specification for this modulation.

Such challenges make it essential to understand any design issues prior to hardware testing. In the research and development (R&D) testing phase, however, system engineers must create and analyze MIMO test signals with enough flexibility to address the large number of spatial streams, bandwidths, and modulation formats supported by IEEE 802.11ac. When measuring the transmitter's output EVM, any problems must be isolated to either the in-phase/quadrature (I/Q) or intermediate-frequency (IF) stages. Alternatively, there could be a crosstalk or timing issue.

To overcome IEEE 802.11ac MIMO system design and test challenges, the note suggests the use of software design simulation to evaluate design-performance tradeoffs. For example, the designer can change the LO phase noise being modeled in dBc/Hz to determine the phase-noise performance required for 256QAM versus 64QAM. Power-amplifier (PA) linearity, I/Q modulator gain/phase impairments, and mixer/filter impairments also can be modeled. In the R&D testing phase, MIMO test signals can be generated by combining the simulation with test equipment. The different spatial streams, bandwidths, and modulation orders supported by IEEE 802.11ac can be addressed. With the addition of wideband oscilloscopes and modular test instruments, MIMO EVM testing can be performed.

Agilent Technologies, Inc., 5301 Stevens Creek Blvd., Santa Clara, CA 95051; (408) 345-8886, www.agilent.com.

Simulation And Modeling Are KEY TO AUTO-ANTENNA SUCCESS

MANY FACTORS CAN impact the effectiveness of the multi-antenna configurations implemented in today's vehicles. Examples include blocking, reflecting or re-radiating energy, and co-site interference. In actual operating conditions, the motion of the vehicle platform and environmental factors like terrain and buildings also can reduce system effectiveness. In addition, radiation hazards may pose risks to nearby personnel. As explained in an eight-page white paper from Remcom, modeling and simulation are critical to overcoming these issues.

Titled "Using Simulation to Optimize Safety, Performance, and Cost Savings When Integrating an Antenna Onto a Platform," the document explains that modeling and simulation can be used to assess options and tradeoffs. A small number of planned approaches can then be selected before any physical testing occurs. Modeling and simulation also eliminate the limitations of physical tests. With a comprehensive modeling and simulation toolset, any number of conditions can be simulated. Physical measurements can be used to confirm simulation-based assessments.

To evaluate potential configurations until a successful option is identified, for instance, high-fidelity electromagnetic (EM) solvers can be used. Using the XFdtd software and an in-house ray-tracing tool, a radiation pattern has been simulated in free space without any vehicle or other obstruction to perturb the pattern. Once the antenna was mounted on a vehicle, that radiation pattern also was simulated. In this case, the antenna exhibited similar forward radiation and gain to the original design.

At higher frequencies, an electrically large scenario may require more computer memory or longer simulation times when performing an EM simulation. Here, a two-step hybrid approach may be used. The note cites an example in which the full-wave method from XFdtd determined the radiation pattern of the array on a metal groundplane. A solution based on the Uniform Theory of Diffraction (UFD) then calculated the radiation pattern resulting from mounting the array to the underside of the electrically large Global Hawk unmanned aerial vehicle (UAV).

Because military vehicles commonly incorporate several antenna systems in close proximity, interference between these systems can cause problems with simultaneous operation. Using simulation and power measurements, the power coupling between each transmit and receive antenna can be assessed to provide an idea of how much transmitted power propagates into the neighboring system. Overall, the paper builds a strong case for the use of EM modeling solutions to predict the performance of an antenna onto a vehicle platform.

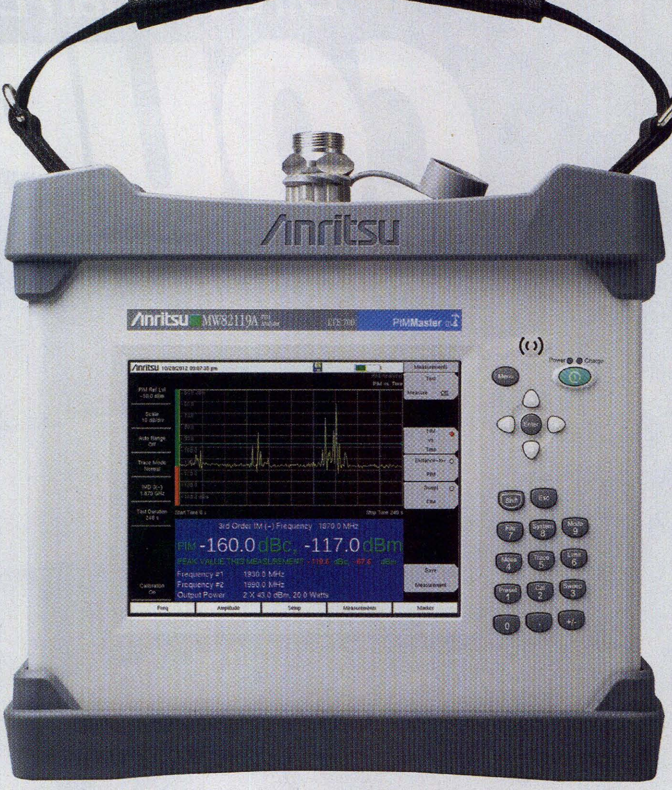
Remcom, Inc., 315 S. Allen St., Ste. 416, State College, PA 16801; (814) 861-1299, www.remcom.com.

JACK BROWNE | Technical Contributor

Portable Analyzers

Find PIM At Cell Sites

These portable, battery-powered analyzers both generate test tones and measure PIM levels at indoor and outdoor remote sites, with models for specific wireless frequency ranges.



1. The MW82119A family of PIM Masters portable instruments can locate PIM sources at cellular and other remote wireless communications sites.

PASSIVE INTERMODULATION (PIM), once relatively unknown in the RF/microwave industry, has become almost a household term when describing the performance of modern wireless communications systems. As its name suggests, PIM is signal distortion that results from the mixing of multiple signals, often in a loose connector or in a rusty termination within the wiring of a cellular communications tower. And because so many modern wireless communications formats are based on multiple carriers, PIM can plague the infrastructure of cellular towers and repeaters.

Fortunately, the latest additions to the PIM Master™ line of portable analyzers from Anritsu Co. (www.anritsu.com) make remote, on-site PIM testing not only possible but practical. They provide all of the measurement capability needed for PIM measurements in portable units that fits into a backpack and operate for several hours on a single battery charge.

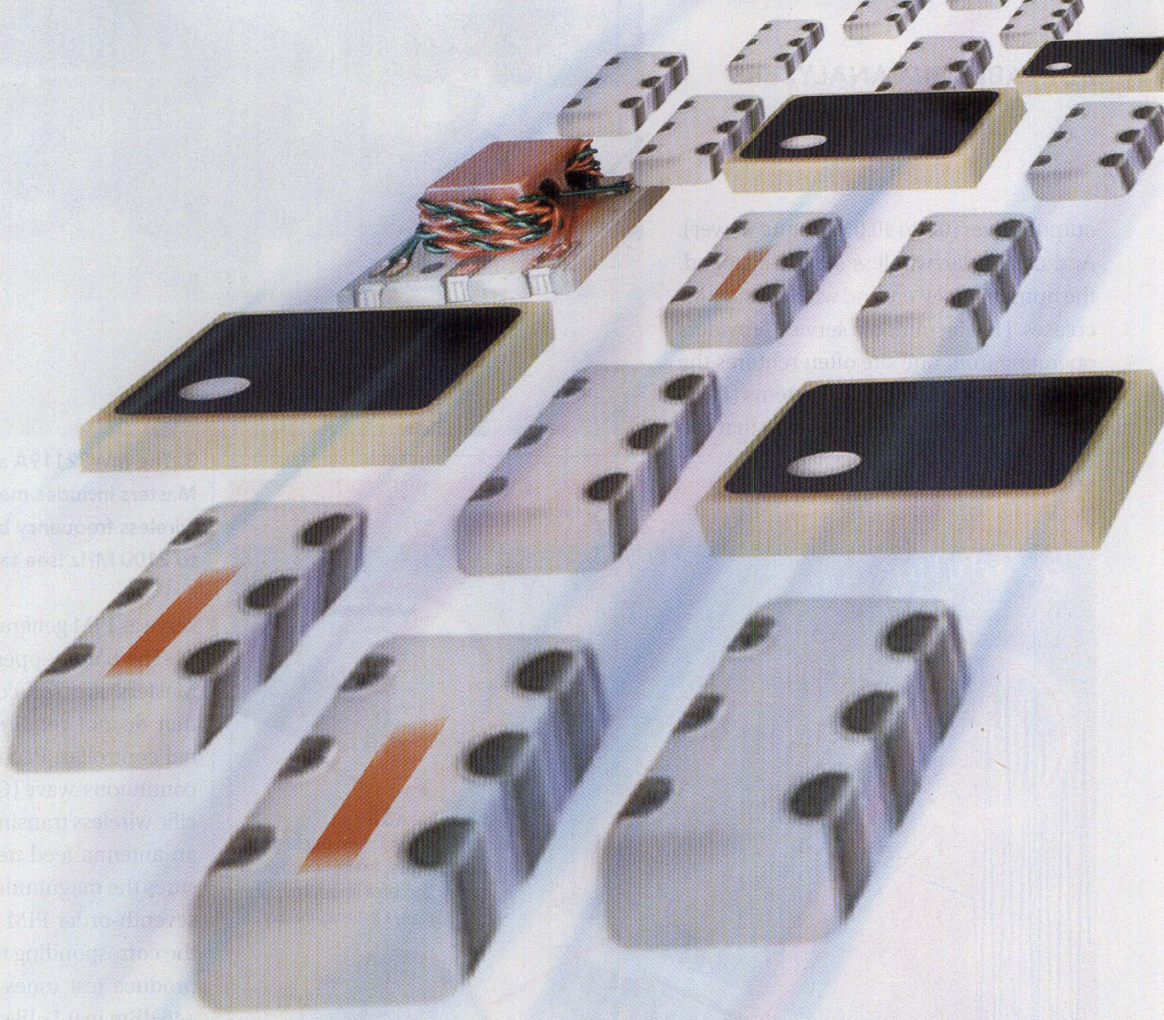
The MW82119A line of PIM Master portable analyzers **(Figs. 1-3)** are small, battery-powered instruments with a highly visible, 8.4-in. (213-mm) touchscreen display for ease of use and visibility under a host of operating conditions. The product family includes different models for specific communications bands, such as 700 MHz for testing Third-Generation (3G) Long-Term-Evolution (LTE) cellular systems and 1900 MHz for checking PIM in Personal Communications Services (PCS) wireless equipment **(see table)**.

2. The battery-powered MW82119A PIM Masters are small and lightweight enough to bring to the top of a cellular communications tower.

These new, lightweight portable test instruments build on the firm foundation established by the company's Site Masters—first introduced in 1997—and more recently its Spectrum Masters, with as much as 95-dB dynamic range from 100 kHz to 6 GHz. In addition, the models MW8208A, MW8209A, and MW8219A PIM Masters introduced last year were also aimed at specific wireless/cellular bands, such as 869 to 894 MHz and 1930 to 1990 MHz.

These battery-powered analyzers easily bring PIM test capability to remote locations, such as the top of cellular towers where RF/microwave transmit/receive electronics are often found. The new MW82119A PIM Masters measure just 13.8 x 12.4 x 6.0 in. (350 x 314 x 152 mm) and will run for as long as 2.5 hours on a single battery charge. Depending upon model, they weigh between 20 and 27 lbs (9 to 12 kg) for ease of transport to a wireless communications site and even up a tower. Since there is typically no AC power available at the top of a cellular tower, the completely self-powered, self-contained operation of the MW82119A PIM Masters makes them ideal for such remote measurements.

Characterizing a communications system and its cables and connectors for PIM requires multiple test signals at sufficient power levels. The MW82119A PIM Masters deliver, boasting a pair of test tones that can each be set at levels from +25 to +46 dBm



output power (0.3 to 40.0 W output power). And as cellular/wireless services expand, the number of towers and wireless sites increases. Having multiple service providers operating from one site often requires the use of distributed antenna systems (DAS) with multiple coaxial connections that can serve as PIM generation points.

3. The MW82119A series of PIM Masters includes models for testing wireless frequency bands from 700 to 2100 MHz (see table).

The battery-operated MW82119A PIM Masters are self-contained test systems that do not require an additional external controller. Each model generates two continuous-wave (CW) test tones in a specific wireless transmit band for injection to an antenna feed network and then measures the magnitude of the third-, fifth-, or seventh-order PIM products that fall into the corresponding receive band. They can produce test tones at levels from +25 to +46 dBm in 0.1-dB steps and feature a PIM measurement range of –130 to –70 dBm.

The MW82119A PIM Masters feature a host of useful automated measurements, including the firm's patented Distance-to-PIM™ measurement capability which helps to isolate the source of PIM in a communications tower or system, as well as in lower-power DAS equipment. A user simply sets a handful of starting parameters, including the two carrier frequencies (F1 and F2); the intermodulation order; the output test power level; the test duration; and lower and upper limit lines. For analyzers equipped with the Global-Positioning-System (GPS) option, that feature can also be turned on or off. For Distance-to-PIM measurements, the distance and the velocity of propagation for the cable under test must also be entered.

Additional automated tests include PIM-versus-time and swept PIM measurements. For PIM-versus-time measurements, the two carrier frequencies F1 and F2 are fixed while the PIM magnitude is measured as a function of time. This measurement, which provides a visual indication of PIM stability with time, is ideal for dynamic PIM testing and for peak PIM

Selecting a PIM Master™			
Model	Application	Transmit range (MHz)	Receive range (MHz)
MW82119A-0700	LTE	734.0 to 734.5 745 to 766	698 to 722 779.5 to 804.5
MW82119A-0850	Cellular	869 to 871.5 881.5 to 894	824 to 849
MW82119A-0900	E-GSM	927.0 to 937.5 951.5 to 960.0	880 to 915
MW82119A-0180	DCS	1805.0 to 1837.5 1857.5 to 1880	1710 to 1785
MW82119A-0190	PCS	1930.0 to 1932.5 1950 to 1990	1870 to 1910
MW82119A-0192	PCS/AWS	1930 to 1935 2110 to 2155	1710 to 1750

measurements for pass/fail testing. When performing swept PIM measurements, carrier frequency F1 can be fixed and frequency F2 swept, or carrier frequency F2 can be fixed and frequency F1 swept, with the results showing PIM magnitude as a function of frequency. The MW82119A PIM Masters feature a front-panel keypad, menu button, arrow keys, and a flash memory drive for data storage. A built-in lithium-ion rechargeable battery provides at least 2.5 hours running time per charge. In addition, each analyzer has an input port for an external power supply, an AC/DC adapter with +12-VDC output, and an automotive power adapter. Each analyzer includes an Ethernet port, two standard USB ports, a mini USB port, and a female SMA connector for a GPS antenna. The MW82119A PIM Masters can be equipped with a GPS receiver as an option. The analyzers can also be shipped with a built-in power meter as an option.

The MW82119A PIM Masters can be used with Anritsu's Line Sweep Tools (LST) software to compare main and diversity path performance levels, evaluate changes over time, and compare performance levels before and after making adjustments to an antenna system. The LST software can be used with each analyzer to create a single-site report showing PIM levels, VSWR, distance-to-fault results, and distance-to-PIM results. Each analyzer can save and recall test setups for standardized testing, and limit lines can be set for visual and/or audible pass/fail criteria.

The new PIM Masters are built for outdoor use, undergoing a 50-hour burn-in period and two-hour thermal cycling. They are designed for operating temperatures from –10 to +55°C, for operating and nonoperating altitudes to 4600 m, and meet MIL-PRF-28800F Class 2 requirements for shock. P&A: 4 to 6 wks. MWRF

Editor's Note: For an expanded version of this article, go to http://mwrf.com/test-amp-measurement-analyzers/portable-analyzers-find-pim-cell-sites.

ANRITSU CO., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; (408) 778-2000, FAX: (408) 776-1744; *www.anritsu.com.*

JACK BROWNE | Technical Contributor

Cables & Connectors Forge Critical Links

Cable and connector configurations are constantly changing to provide improved electrical performance and greater ease of use at ever-higher frequencies.

Cables and connectors are often thought of as "patches" to get a high-frequency signal from one location to another. While their roles in a system may be that simple, they can also have a major influence on the performance of that system. For that reason, cables and connectors should always be chosen wisely for RF/microwave applications, with performance levels that exceed the requirements of those applications.

Coaxial connectors are designed to be electrically "invisible" as much as possible, providing interfaces for component packages, circuit boards, and coaxial connectors with the lowest possible insertion loss and VSWR. In recent years, coaxial connectors have been extended to higher frequencies, accommodating broadband components and test equipment operating into millimeter-wave frequency ranges.

A connector's frequency range is a function of its inner pin diameter. The smallest-dimension RF/microwave connectors, with 1-mm pin diameter, provide frequency coverage as wide as DC to 110 GHz, increasingly replacing more narrowband millimeter-wave waveguide flanges as the interconnection of choice. As millimeter-wave applications, such as 60-GHz point-to-point radios, expand, the demand for higher-frequency connectors operating through 40 GHz and higher also grows.

In addition, specifiers are generally seeking coaxial connectors in a variety of different mechanical configurations, from traditional end-launch connectors to blind-mate and vertical printed-circuit-board (PCB) launch connectors for fabricating compact multilayer circuit boards.

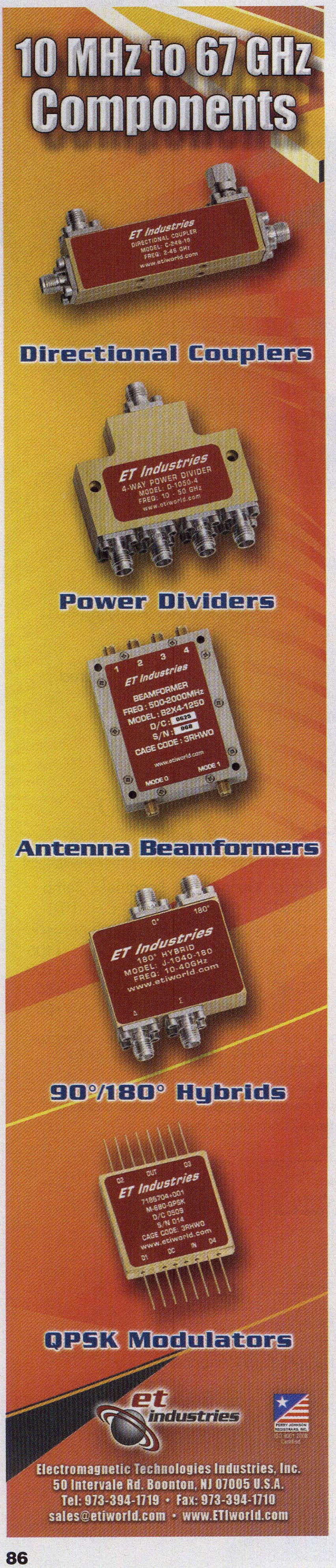
1. This line of vertical-launch 2.4-mm coaxial connectors can support a continuous bandwidth of DC to 50 GHz. [Photo courtesy of Molex, Inc. (www.molex.com)].

For example, Molex, Inc. (www.molex.com) recently introduced a high-speed vertical-launch 2.4-mm connector capable of operation to 50 GHz **(Fig. 1)**. Designed for mounting anywhere on a PCB to allow increased circuit and interconnection density, these connectors feature a compression-mount design to simplify mounting high-frequency connectors to a PCB. The connector receptacle attaches to a PCB by means of two 0-80 UNF screws.

The connectors accommodate a wide range of board thicknesses including 0.57 to 2.79 mm with a continuous ground connection between the connector and the PCB. The connectors, with a stainless-steel body built to handle over 500 mating cycles, exhibit low VSWR of 1.20:1 through 50 GHz.

For those interested in the long evolution of RF/microwave coaxial connectors, an application note from Maury Microwave (www.maurymw.com)—"Microwave Coaxial Connector Technology: A Continuing Evolution" (Application Note 5A-021), written by Mario Maury, Jr.—is available for free download from the firm's website. The 21-page application note details some of the long evolution of RF/microwave coaxial connectors to their current configurations.

As the note explains, coaxial connectors are available in both sexless and sexed forms. Sexless connectors join two identical halves while sexed connectors have male and female connector halves, usually with both conductors employing male and female configurations. The note also describes three different grades of connectors that are commonly used in the high-frequency industry: production, instrument, and metrology. The precision and performance accuracy/repeatability improves with each connector grade, as does the cost, with metrology-grade connectors providing traceability to national standards.



2. The SRX line of coaxial cable assemblies is available with all three types of RF/microwave cables—semirigid, hand-formable, and flexible cables—with levels of PIM as low as –174 dBc depending on cable and connector types. [Photo courtesy of Santron, Inc. (www.santron.com).]

Coaxial cables are also evolving, with a growing number of suppliers for specialized cable assemblies [including those with hand-formable cables, low passive-intermodulation (PIM) performance, and phase-stable cables]. The choice of cable assemblies was once between those based on semirigid cables and those with flexible cables. Semirigid coaxial cables provide superior electrical performance but cannot be bent to shape without special tools. Flexible coaxial sacrifice some of the electrical performance of semirigid cables, but provide ease of installation through easy bending and shaping.

A third type of cable assembly, the hand-formable cable, is becoming more popular since it features electrical performance that is between the levels offered by semirigid and flexible cables, but can be readily shaped to fit an application. It is well suited for many system and test-equipment applications that require high performance, but may also need last-minute or on-site shaping of the cable assembly to make proper connections.

Hand-formable cable assemblies are designed for a limited number of flexures— typically about 500—and are typically supplied in cable diameters that match to the sizes of semirigid cables, such as 0.047 and 0.141 in. The similar cable diameters allow the use of similar connectors with hand-formable cables, and for ease of replacement of semirigid cables as needed.

Some component suppliers, such as Micro-Coax (www.microcoax.com), feature all three types of RF/microwave coaxial cables in their cable assemblies. The firm actually offers two different types of hand-formable cables, Alumiline cables with solid aluminum jackets and UTiFORM cables with tinned-braided outer jackets. The former delivers higher RF shielding and performance closer to semirigid cables, while the latter offers somewhat greater flexibility for ease of installation. Both hand-formable cable types are available in the same sizes as semirigid cables, such as with 0.047- and 0.141-in. diameters, allowing the use of the same connector sizes as for semirigid cables.

Mini-Circuits (www.minicircuits.com) supplies its 141 Series of Hand-Flex cables as a replacement for 0.141-in. semirigid cables. These hand-formable cables, which operate from DC to 18 GHz, are designed for high power-handling capabilities, with ratings of over 500 W at 500 MHz and 90 W at 18 GHz. The 141 Series cables have a bend radius of 8 mm for forming tight shapes, with standard assemblies supplied with an FEP insulator jacket to minimize shorting during installation and use; versions are also available without the FEP jacket.

SUCOFORM hand-formable cables from Huber + Suhner (www.hubersuhner.com) leverage the positive qualities of standard PTFE-insulator-based semirigid cables, but use a tin-soaked copper braid for the outer conductor for enhanced flexibility.

The hand-formable cable assemblies

> Specifiers are generally seeking coaxial connectors in a variety of mechanical configurations, **from end-launch to PCB connectors.**

from WL Gore (www.gore.com) are also available in versions equivalent to 0.086- and 0.141-in. semirigid cables for applications from DC to 18 GHz. The smaller-diameter hand-formable cables have a minimum bend radius of 0.20 in. and maximum insertion loss of 0.98 dB/ft. at 18 GHz, while the larger-diameter cables offer a minimum bend radius of 0.25 in. with maximum insertion loss of 0.65 dB/ft. at 18 GHz.

Modern communications systems with their advanced modulation formats often require cable assemblies with exceptional phase stability and/or low PIM generation. A growing number of cable suppliers now offer cables and assemblies based on materials known to minimize PIM. Ferromagnetic materials (nickel, for example) can increase the level of PIM in a cable assembly or other high-frequency component, especially when operating under multiple-signal-tone conditions. Poor-fitting connection junctions and rust on metal surfaces can also contribute to unwanted PIM distortion in a communications or test system.

In addition to supplying numerous low-PIM cables and cable assemblies, San-tron (www.santron.com) offers a free white paper to help specifiers better understand the causes and effects of PIM in cables and connectors: "Minimizing PIM Generation from RF Cables and Connectors." The eight-page document, available as a free download (http://www.santron.com/Documents/PIM%20White%20Paper.pdf), offers useful advice for specifiers hoping to curb the levels of PIM from the cables and connectors in their systems. The firm's SRX™ line of low-PIM cable assemblies are available based on semirigid, hand-formable, and flexible cable types (**Fig. 2**).

What is considered acceptable PIM performance? That answer will depend on the requirements of a particular system, and some forms of advanced digital modulation are less forgiving of PIM than others. As an example, cables and connectors are among the most PIM-prone components in many systems. The LMR-SW™ cables from Times Microwave Systems (www.timesmicrowave.com) have been developed for applications where PIM must be minimized. They feature a thin-wall aluminum outer conductor and can achieve better than −170 dBc PIM performance. A line of Type N connectors developed by Pasternack Enterprises (www.pasternack.com) was designed to terminate these cables with minimal additional PIM. The connector body is brass with white bronze plating, while contacts are gold plated and nickel free. The connectors, usable to about 11 GHz, are interchangeable with any Type-N connector meeting MIL-C-39012 specifications.

To ease the task of specifying coaxial cable assemblies, some suppliers, including Times Microwave Systems, provide online calculators that can be used to compute the attenuation (in dB/100 ft.) for a desired length of coaxial cable for a specific frequency (in MHz). The calculator, available at http://www.timesmicrowave.com/cgi-bin/mobile-calculate.pl, can also predict the power-handling capability of a given type of cable assembly. MWRF

USB Switch Matrix Routes DC To 18 GHz

This rugged, versatile SP4T switch matrix boasts outstanding electrical performance and ease of use.

SWITCHING SIGNALS in a broadband test setup or other system can require careful planning and placement of low-loss switches. Poorly conceived switching strategies can introduce unwanted delays and other signal distortions to the measurement setup. Alternately, it can be handled simply by adding a model USB-1SP4T-A18 low-cost Universal-Serial-Bus (USB) switch matrix from Mini-Circuits (www.minicircuits.com).

This rugged, low-cost single-pole, four-throw (SP4T) switch matrix operates from DC to 18 GHz with low loss and high isolation, and can handle signal power levels as high as 2 W (+33 dBm). For ease of use, the switch matrix is even supplied with operating software and a USB cable for control by a personal computer (PC) running Microsoft Windows® or Linux® operating systems, allowing a user to set any required switching configuration or sequence.

The model USB-1SP4T-A18 SP4T switch matrix **(see figure)** is supplied in a rugged metal case measuring 4.5 x 6.0 x 2.25 in. with SMA input connector and four SMA output connectors, a 2.1-mm DC socket, and a type B USB port. It uses absorptive failsafe break-before-make RF electromechanical switches designed for long operating lifetime—typically 100 million switching operations when channeling signal power levels of 100 mW or less (and shorter expected operating lifetimes at higher signal power levels). The metal housing also incorporates low-loss RF/microwave transmission lines carefully matched in length to minimize variations in signal-path propagation, and a dedicated microprocessor for control of the switching functions under automatic software programming.

Model USB-1SP4T-A18 SP4T is a broadband USB-controlled SP4T switch matrix capable of 85-dB typical isolation with low insertion loss and low VSWR from DC to 18 GHz.

The broadband switch matrix is supplied with a compact disc (CD) containing a graphical-user-interface (GUI) program; the latter features an API DLL object compatible with 32- and 64-b computer operating systems. It is also shipped with a 2.7-ft. USB cable and a power adapter to furnish the 300 mA at +24 VDC needed for operation. The power adapter/supply is suitable for use both in the United States and European Union, in addition to other power systems around the world. The switch matrix can be used with all leading test software programs, including Agilent VEE® from Agilent Technologies (www.agilent.com), LabVIEW® from National Instruments (www.ni.com), and MATLAB® from MathWorks (www.mathworks.com).

In terms of performance, the USB-1SP4T-A18 SP4T switch matrix channels signals quickly and without distortion. It features 25-ms typical switching time with insertion loss of typically 0.1 dB to 1 GHz, 0.15 dB to 8 GHz, 0.25 dB to 12 GHz, and 0.45 dB to 18 GHz. The VSWR is typically 1.05:1 to 1 GHz, 1.20:1 to 12 GHz, and 1.29:1 to 18 GHz, while the isolation per switch is typically 100 dB to 1 GHz, 90 dB to 8 GHz, 85 dB to 12 GHz, and 60 dB to 18 GHz.

The versatile USB-controlled switch matrix can greatly simplify signal routing requirements in test setups and communications and other systems. With its high isolation between ports and low insertion loss, it ensures minimal modification of any signals passing through it with efficient routing of signals according to either manual or programmed control. The switch matrix is designed for an operating temperature range of 0 to +40°C; it can be used with its own GUI software or programmed with the included API DLL.com object for use with many other test and system-level software programs. Additional USB cables and a mounting bracket are available as options. P&A: $795 (1 to 9 qty.); stock.—*JB*

MINI-CIRCUITS, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, FAX: (718) 332-4661, *www.minicircuits.com.*

MARCH 2013 ISSUE PREVIEW

Ad Close 2/15/2013 • Ad Materials due 2/28/2013

Theme: Passive Components

Industry Insight: Satcom Components

Product Trends: Industrial, Scientific, & Medical

RF Essentials: Couplers & Dividers

Industry Events - Bonus Distribution: Satellite 2013, March 18-21 Washington, DC

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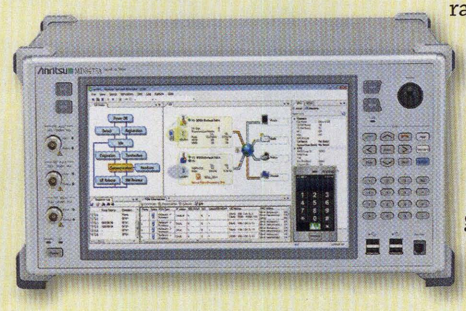
Tester Tackles Voice Over LTE

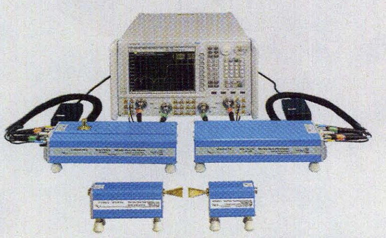
The MD8475A Signaling Tester can now confirm operation of services, such as Call Forwarding and Call Waiting, under a variety of network conditions, extending its Voice-over-Long-Term-Evolution (VoLTE) testing capabilities. The MD8475A's new Supplementary Service option enables functional testing of Call Forwarding, Call Waiting, Call Hold, Identification Presentation, and Identification Restriction. The tester supports a combination of environments, including testing LTE, GSM, and WCDMA cellular networks. It tunes from 0.35 to 3.60 GHz with 100-kHz resolution and covers a signal level range from −130 to −10 dBm with 0.1-dB resolution. The tester features excellent spectral purity, with harmonic levels of −25 dBc or better and spurious signal levels of −40 dBc or better. The SmartStudio graphical-user-interface (GUI) software provides easy graphical control of the MD8475A.



ANRITSU CO., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; (408) 778-2000, FAX: (408) 776-1744, *www.anritsu.com*.

VNA Modules Aid Antenna Testing

A line of compact modules from OML for vector network analyzers (VNAs) helps characterize millimeter-wave antennas from 50 to 500 GHz. The modules are compatible with modern VNAs, including antenna test systems from Nearfield Systems (www.nearfield.com). The modules, which are available in RoHS compliant versions for WR-10, WR-05, WR-03, and WR-02.2 frequency bands, enable a small variable-positioning pedestal for characterizing antennas in terms of gain, polarization, and antenna pattern for both near- and far-field operation. The waveguide flange interface used on the modules is compatible with MIL-DTL-3922/67D.



OML, INC., 300 Digital Dr., Morgan Hill, CA 95037; (408) 779-2698, *www.omlinc.com*.

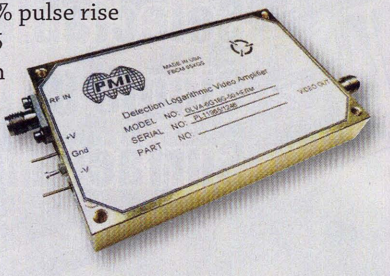
Amplifier Stays Flat From 0.01 To 6.00 GHz

Model CMA-62+ is a RoHS-compliant wideband amplifier with extremely flat gain from 0.01 to 6.00 GHz. The small-signal gain, which is typically 15.4 dB at 2 GHz, remains within ±0.7 dB from 50 to 4000 MHz. The amplifier delivers +19 dBm typical output power at 1-dB compression at 2 GHz. It offers a wide dynamic range, with a third-order intercept point of typically +39 dBm at 50 MHz and +33 dBm at 2 GHz. Based on GaAs heterojunction-bipolar-transistor (HBT) technology, the monolithic-microwave-integrated-circuit (MMIC) amplifier is bonded to a low-temperature-cofired-ceramic (LTCC) substrate and housed in a hermetic package measuring just 3.00 x 3.00 x 1.14 mm.

MINI-CIRCUITS, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, FAX: (718) 332-4661; *www.minicircuits.com*.

DLVA Processes Pulses From 6 To 18 GHz

Model DLVA-6G18G-50-HERM is a detector log-video amplifier (DLVA) with frequency range of 6 to 18 GHz. It offers a logging range of −70 to 0 dBm with tangential signal sensitivity (TSS) of −72 dB. The DLVA, which can handle pulsed signals as short as 100 ns through continuous-wave (CW) signals, has maximum 10%/90% pulse rise time of 50 ns and maximum 90%/10% pulse fall time of 70 ns. The logarithmic slope is 25 mV/dB with logarithmic accuracy of ±4 dB. The DLVA features a recovery time of less than 70 ns with delay time of less than 15 ns. The amplifier draws 400 mA maximum current from a +12-VDC supply and 250 mA maximum current from a −12-VDC supply. It is supplied in a hermetically sealed housing measuring 3.20 x 2.05 x 0.40 in.



PLANAR MONOLITHICS INDUSTRIES, INC., 7311-F Grove Rd., Frederick, MD 21704; (301) 662-5019, FAX : (301) 662-1731, e-mail: sales@pmi-rf.com, *www.pmi-rf.com*.

Directional Couplers Extend To 40 GHz

A pair of stripline directional couplers from Krytar—models 102040020 and 102040020K—provide broad frequency coverage from 2 to 40 GHz with 2.4- and 2.9-mm female SMA connectors, respectively. Suitable for commercial wireless and military electronic-warfare (EW) applications, the directional couplers exhibit nominal ± 1 dB coupling flatness and frequency sensitivity of ±0.7 dB. The directivity is better than 15 dB to 20 GHz and better than 11 dB to 40 GHz. Insertion loss is less than 1.2 dB to 20 GHz and less than 1.8 dB to 40 GHz. The maximum VSWR is 1.50:1 through 20 GHz and 1.70:1 through 40 GHz. Both couplers are rated for 20 W average power and 3 kW peak power. They both measure 1.75 x 0.40 x 0.65 in. and weigh 1.2 oz. They are designed for operating temperatures from −54 to +85°C.

KRYTAR, INC., 1288 Anvilwood Ave., Sunnyvale, CA 94089; (408) 734-5999, (877) 734-5999, FAX: (408) 734-3017, e-mail: sales@krytar.com, *www.krytar.com*.

Solutions Simplify Location Testing

This software/hardware test system enables end-to-end system characterization of a range of wireless positioning technologies under real-world signaling conditions.

LOCATION TECHNOLOGY has become an integral part of modern life, with wireless chipsets supporting positioning capabilities such as Global Navigation Satellite System (GNSS) and Assisted GNSS (A-GNSS) now included in many handheld devices. A-GNSS is just one location technology—in addition to the use of cellular systems, Wi-Fi, and sensors—used to provide location information. Many location-finding devices combine data from several positioning technologies for improved accuracy.

With the combination and integration of multiple location technologies into portable devices, of course, comes a significant and complex challenge to validate the hybrid performance of the devices. Fortunately, the Hybrid Location Technology Solution (HLTS) from Spirent Communications (www.spirent.com) can be tailored to characterize different hybrid scenarios and RF emulation, based on a combination of location technologies.

HLTS can create actual operating conditions, such as uplink and downlink signal loss and free-space path loss (in IEEE 802.11 systems). This enables testing devices with location capabilities in the laboratory under controlled, repeatable conditions, reducing the time needed for field testing. HLTS also validates hybrid or multiple-location-system operation.

One component of HLTS, the GSS6700 GNSS simulation system, can simulate as many as 12 simultaneous channels for each satellite constellation. HLTS includes the GSS6700 instrument for signal generation and analysis and the SimSENSOR software for programming and control.

For Wi-Fi or WLAN simulations per IEEE 802.11 a/b/n standards, HLTS uses the GSS5700 simulation system to produce the required simulation signals at 2.4 GHz. It can produce 1 to 14 operating channels and 12 independent access points (APs) in a simulated Wi-Fi/WLAN system.

The HLTS test system works with the SimHybrid GUI to synchronize simulation or playback of A-GNSS, Wi-Fi, sensor, and cellular positioning technologies.

HLTS employs the SimHybrid™ software and a graphical user interface (GUI) to synchronize simulation or playback of A-GNSS, WiFi, sensor, and cellular positioning technologies. SimHybrid enables interactive testing by allowing complete flexibility to model real-world scenarios with the inclusion of advanced parameters for motion, RF emulation, antenna characteristics, atmospheric effects, path loss values, and multipath propagation parameters (**see figure**).

HLTS provides two operating modes: simulation, and record and playback. In simulation mode, the HLTS GUI, SimHybrid, allows a user to create a scenario from scratch. Simulation mode provides the ability to model the real world and characterize certain aspects of a device performance under particular conditions.

The main goal of the record and playback mode is to bring the field conditions into the lab. Playback mode utilizes recording devices to capture the field data, and then replay the field data using laboratory instruments. Data from different location technologies can be collected simultaneously on the same time scale and replayed.

HLTS employs two approaches for collecting and replaying field data. In the first, working with processed information from high-performance receivers, Wi-Fi, GPS, and cellular signals can be decoded and the key elements required for positioning recorded synchronously. These signal elements can then be fed to simulators that generate the required RF signals to exercise a device under test to varying field conditions. In the second approach, using recorded RF captured by specialized receivers, the actual field RF can be recorded over a set spectrum.

Spirent's HLTS is an industry leading test solution that integrates four different location technologies into one system, boasting software that simulates and controls the actual environments of location-finding satellites, APs, cellular towers, and sensors. Providing several advantages over field testing, HLTS allows for repeatable conditions, isolation of specific conditions and regression/stress testing.—*JB*

SPIRENT COMMUNICATIONS, 26750 Agoura Rd., Calabasas, CA 91302; (800) SPIRENT, (818) 676-2683, e-mail: sales@spirent.com, *www.spirent.com*.

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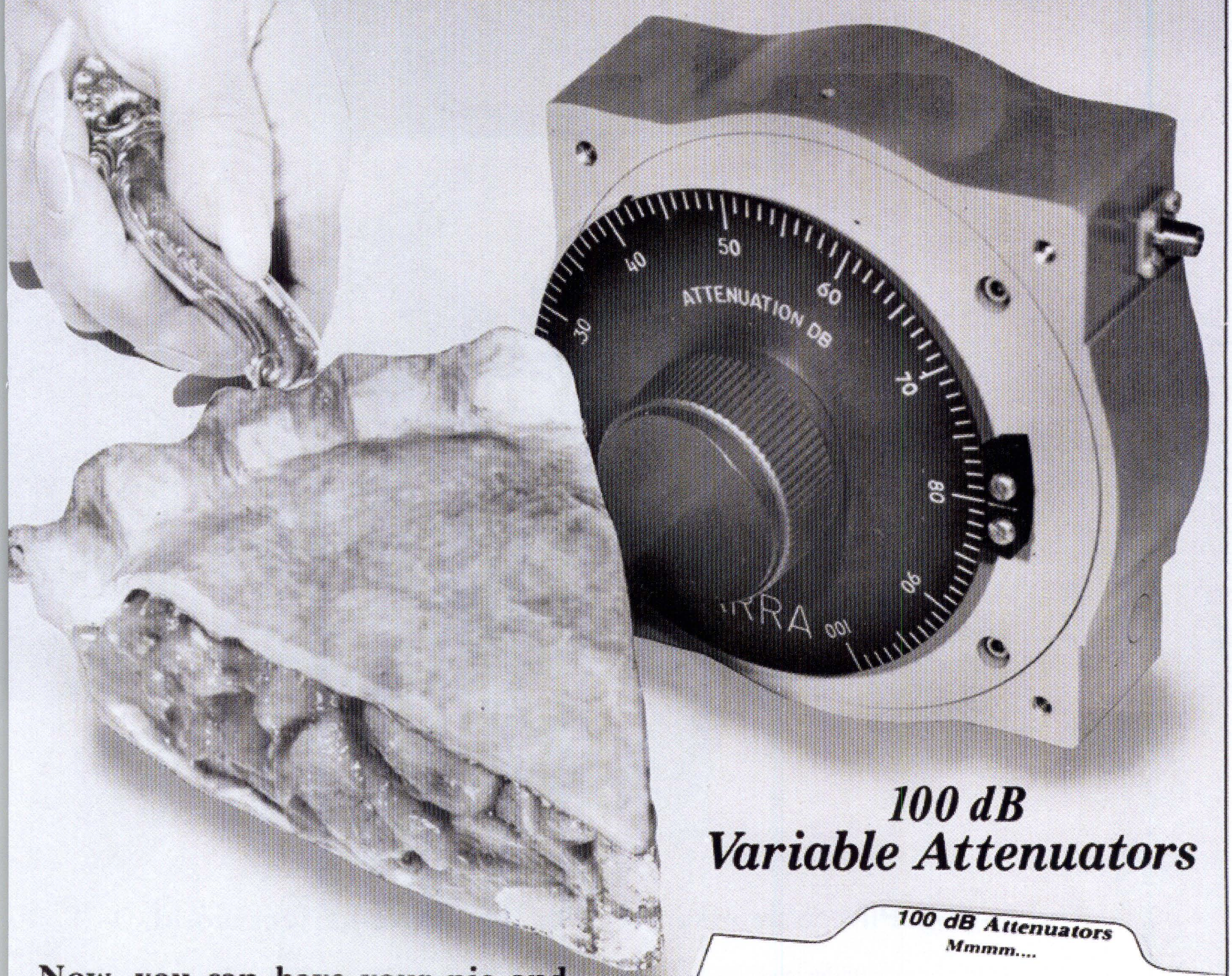

100 dB Variable Attenuators

100 dB Attenuators
Mmmm....

Freq Range	Atten vs Freq dB	Model #
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900 - 1300 MHz	0.75	2-3952 - 100
1000 - 2000 MHz	1.5	3952 - 100X
2000 - 4000 MHz	1.5	4952 - 100 X
4000 - 8000 MHz	1.5	5952 - 100X

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