Vol. 52 • No. 3

March 2009

Microwave Journal

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Test and Measurement

Test Solutions Soup Up for 4G

RFID Pre-compliance Testing

Strategies for MIMO Testing

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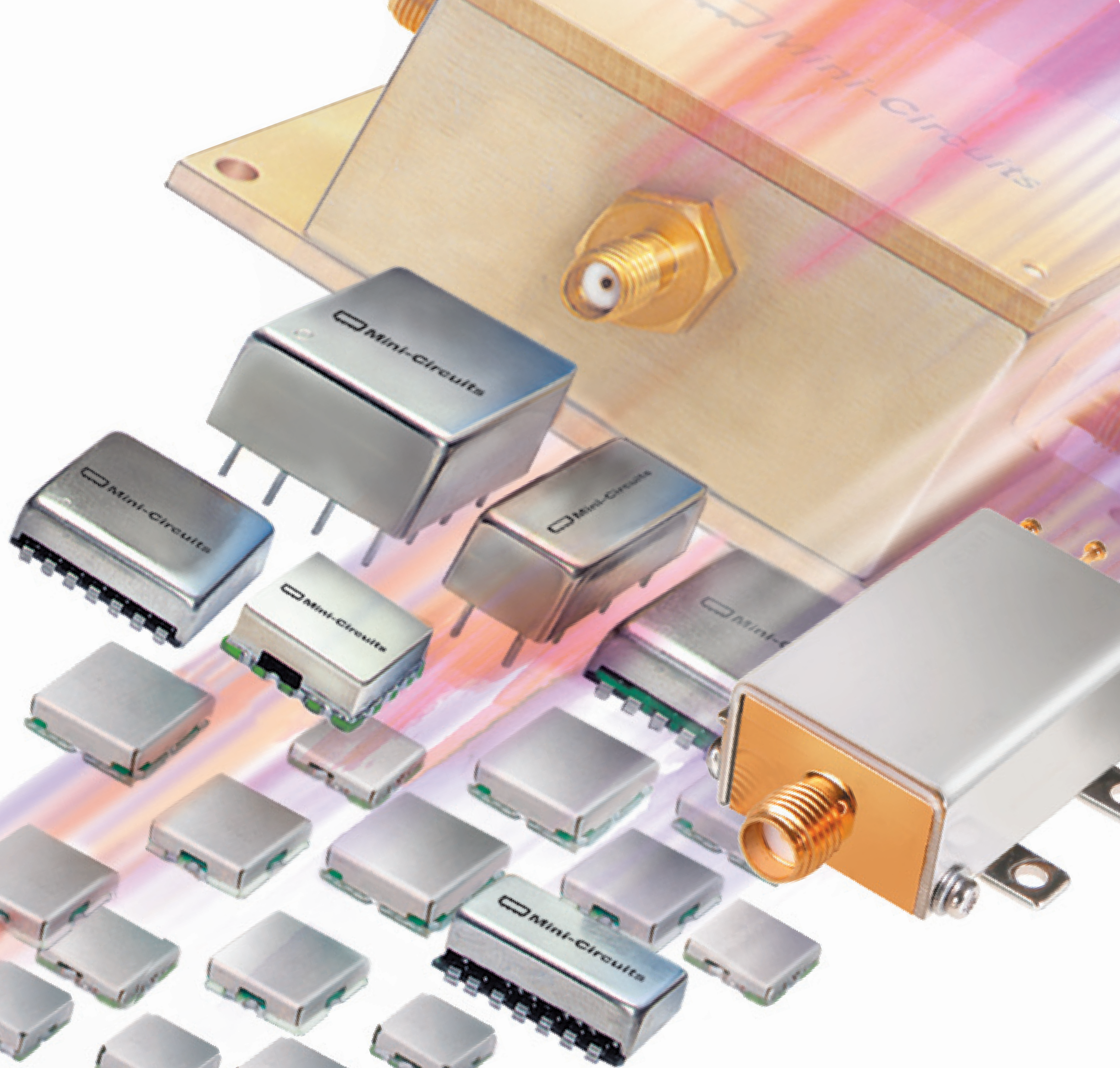
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MODEL	FREQUENCY RANGE (GHz)	CONNECTOR TYPE	VSWR MATCHING RANGE	MAX. LOSS (PROBES RETRACTED)	PROBES CROSSOVER FREQUENCY (GHz)	POWER[1] HANDLING (AVE./PEAK WATTS)	CARRIAGE TRAVEL INCHES	(CM)	OVERALL LENGTH INCHES	(CM)
7941A	12.0 – 50.0	2.4mm	10:1	1.0 dB	21.5	15/150	0.417	(1.059)	4.62	(11.735)
8041C	12.0 – 34.0	3.5mm	10:1	0.7 dB	16.0	15/150	0.417	(1.059)	4.95	(12.573)
8045D1 2640D1 1643D1	1.8 – 18.0	3.5mm 7mm Type N	12:1	0.4 dB	5.5	25/250 50/500 50/500	3.4 3.4 3.4	(8.636) (8.636) (8.636)	8.94 8.88 8.92	(22.708) (22.555) (22.657)
8045P 2640P 1643P	0.8 – 18.0	3.5mm 7mm Type N	10:1	0.5 dB	4.6	25/250 50/500 50/500	7.8 7.8 7.8	(19.812) (19.812) (19.812)	13.34 13.28 13.32	(33.884) (33.731) (33.833)
1643N	0.8 – 2.5 2.5 – 8.0	Type N	25:1 18:1	0.5 dB	2.8	50/500	7.8	(19.812)	13.32	(33.833)
2640N	0.8 – 2.5 2.5 – 8.0	7mm	25:1 18:1	0.5 dB	2.8	50/500	7.8	(19.812)	13.28	(33.731)
8045N	0.8 – 2.5 2.5 – 8.0	3.5mm	25:1 18:1	0.5 dB	2.8	25/250	7.8	(19.812)	13.34	(33.884)
2740B 2440B	0.8 – 8.0	7-16 14mm	35:1	0.1 dB	2.8	100/100	7.88 7.88	(20.015) (20.015)	14.48 13.07	(36.779) (33.198)
2740C 2440C	0.4 – 4.0	7-16 14mm	25:1	0.1 dB	1.4	100/100	14.95 14.95	(37.973) (37.973)	22.76 21.35	(57.810) (54.229)

[1] Within Rated Matching Range

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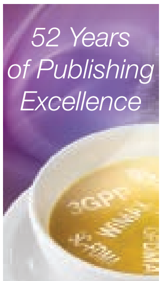
MARCH 2009 VOL. 52 • NO. 3

FEATURES



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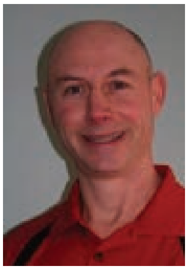
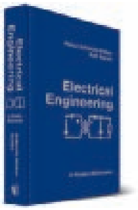
Executive Interview



MWJ talks to **Frank Wodoslawsky**, President and CEO of **Weinschel Associates**. Frank talks about the company's tradition of excellence in engineering, designing custom components for niche applications and taking on the jobs that larger companies are passing up.

Expert Advice

Mark Elo, Marketing Director of RF Products for **Keithley Instruments**, shares his thoughts on the challenges of moving communications from SISO to MIMO.



Read the advice from this industry expert, respond with your comments and win a complimentary copy of *Electrical Engineering: A Pocket Reference* from Artech House (see www.mwjournal.com for details).

MWJ Blog

MRF test equipment is constantly evolving. In the past year, we've witnessed many advances in real-time digital oscilloscopes, signal and spectrum analyzers, communication and MIMO testing and nonlinear vector network analyzers. This month's test & measurement theme is expanding on our blog. Read http://microwavejournal.blogspot.com and add your comments.

Online Technical Papers

3D EM Simulation in the Design Flow of High-speed Multi-pin Connectors

Thomas Gneiting, AdMOS GmbH and Adrian Scott, CST AG

LTE Ready Backhaul

Aviv Ronai, Chief Marketing Officer, Ceragon Networks

Power Amplifier Savings with DC-DC Converters in GSM-GPRS-EDGE Mobile Handsets

Oleksandr Gorbachov, Contractor and Mario Paparo, ST Microelectronics

Part III: 3G/4G Multimode Handset Challenges: Implications for Front End Architecture Options

Kevin Walsh and Jackie Johnson, RFMD

Why CTIA Wireless Matters

CTIA WIRELESS 2009 is the largest and most comprehensive US tradeshow in the wireless industry, so it should be a prime show for the RF/microwave industry. It is the convergence of more than 1,200 exhibiting companies, dozens of industries, and over 40,000 professionals from 125 countries all working toward the common goal of promoting wireless. It is the premier venue to exchange ideas, create partnerships and collaborate on wireless telecommunications, and the RF and microwave industry is a key contributor to most of the technologies involved. However, many of the component and smaller RF/microwave companies have left the show over the years as they seemed to get lost in the consumer glamour of the big handset manufacturers like LG, Motorola, Samsung, Apple, Sony/Ericsson, etc., not to mention the service providers and applications suppliers.

But what better place to network, meet with customers and show off new RF/microwave technologies than at the show where most of the wireless OEMs exhibit. What if all of the component and smaller RF/microwave related companies were in one concentrated area so that they could raise a significant presence and not be lost among all of the enormous booths of the big conglomerates? Let's bring back the RF/microwave industry content!

With this in mind, *Microwave Journal* has organized the first RF/Microwave Pavilion at CTIA Wireless 2009. This new pavilion will congregate companies in the RF/microwave field in one location to create a dynamic presence. By showcasing in one dedicated area, the pavilion will be the focal point at the show for RF/microwave technology. This offers RF/microwave companies a low cost avenue to return to CTIA and not be lost in the sea of the larger OEMs and providers plus make their presence count at this large show. The small investment to attend such a large show with all of the important OEMs on site should provide a high ROI and customers will know where to find them.

Along with interaction with the OEMs, the RF/microwave companies get the rare chance to interact with the carriers and end consumers to see which features they really need or desire and be able to translate those back into their designs. Meeting with your customer and your customer's customer can often give keen insight into future developments. From a business perspective, the OEM and consumer confidence levels and economic state can be a leading indicator of the level of future business for RF/microwave companies. There is a very large international audience with representatives from over 125 companies, so there are chances to view the global state of the business and discuss partnerships/opportunities with companies from around the world. We often hear from exhibitors at RF/microwave industry specific shows that they are not very successful from a business perspective because the audience is primarily their competitors so only the technical portion is worthwhile. Shows like CTIA Wireless offer exposure to new customers and industries without spending most of your time talking to your peers and competitors.

The RF/Microwave Pavilion will be located on a main aisle near the Machine-to-Machine (M2M) Zone that features exhibitors with pioneering wireless M2M services and products. M2M solutions include wireless remote control and monitoring of fixed and mobile devices for enterprise and consumer markets so it compliments the RF/Microwave Pavilion offering. It also hosts seminars and presentations on Asset Tracking, Sustainable M2M Investments and Open Wireless Initiatives that will be interesting to many in the RF/microwave audience and attract visitors. Perhaps a similar seminar series can be added to the RF/Microwave Pavilion in 2010.

CTIA Wireless has educational seminars and forums for the business and technical visitor offering such items as the Broadband World Forum Unwired, Tower Technology Summit, Wireless University, Mobile Entertainment, Green Telecom Summit, Mobile Marketing/Advertising, Path to 4G, IP Backhaul, etc. There will be many discussions about WiMAX versus LTE this year and the resurgence of microwave backhaul. Not to mention a high power keynote speaker, the honorable Al Gore, and top notch entertainment such as Billy Crystal.

We hope that the RF/Microwave Pavilion will increase the relevancy of the RF/microwave industry to CTIA Wireless and revive the RF/microwave industry's return to the event. This will give us a louder voice to influence the industry direction and objectives while providing the exhibiting companies a valuable venue to meet customers, network and form partnerships (find more information at www.mwjournal.com/Events/).

Patrick Hindle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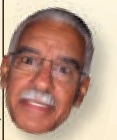
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		30 **Reverberation Chamber Theory and Experiment Short Course** Stillwater, OK **Agilent's High Speed Design Training** Santa Clara, CA	1 **CTIA with RF/Microwave and M2M Zones** Las Vegas, NV **World Radar Fair** Beijing, China	2	3	4
5 **CST MWS A&M CST MICROWAVE STUDIO® Antenna and Microwave** Framingham, MA	6	7 **Don't forget to book your Virtual Trade Booth for the MWJ Online Show Daily at this year's MTT-S IMS exhibition. Inquire at mwj@mwjournal.com.**	8	9	10	11
12	13 **CST MWS A&M CST MICROWAVE STUDIO® Antenna and Microwave** Dallas, TX	14 **Ansoft HFSS Training** Irvine, CA **ITAC and GSA Conference** Ontario, Canada	15 **CST North American User Group Meeting** Dallas/Fort Worth, TX	16 **Ansoft HFSS Training** San Jose, CA	17	18
19	20 **WAMICON** Clearwater, FL **ARMMS RF and Microwave Society Conference** Oxfordshire, UK	21 **Agilent RF and Microwave Fundamentals Course** Schaumburg, IL **MWJ/Besser Webinar: MIMO** *Doug Morais* 	22	23	24	25  **Guglielmo Marconi's Birthday 1874**
26	27 **IDEF 2009** Istanbul, Turkey	28 **AWR Microwave Office for Designers** San Jose, CA	29	30		

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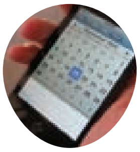

Coming Events

CALL FOR PAPERS

ARMMS RF and Microwave Society Conference
Deadline: March 12, 2009

COMCAS 2009
Deadline: June 15, 2009

ONLINE

MWJ Show Coverage of SATELLITE 2009
Post date: March 31, 2009

MWJ Show Coverage of CTIA Wireless 2009
Post date: April 7, 2009

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MARCH

CST European User Group Meeting
March 16–18, 2009 • Darmstadt, Germany
www.cst.com

IWCE 2009
March 16–20, 2009 • Las Vegas, NV
www.iwceexpo.com

SATELLITE 2009
March 24–27, 2009 • Washington, DC
www.satellite2009.com

APRIL

CST Innovations 2009 Workshop Series
April 1, 2009 • Stellenbosch, South Africa
www.cst.com

CTIA with RF/Microwave and M2M Zones
April 1–3, 2009 • Las Vegas, NV
www.ctiawireless.com

CST North American User Group Meeting
April 15, 2009 • Dallas/Fort Worth, TX
www.cst.com

WAMICON 2009
IEEE Wireless and Microwave Technology Conference
April 20–21, 2009 • Clearwater, FL
www.wamicon.org

ARMMS RF and Microwave Society Conference
April 20–21, 2009 • Oxfordshire, UK

MAY

IEEE Radar Conference
May 4–8, 2009 • Pasadena, CA
www.radarcon09.org

MIE 2009
Microwave Industry Exhibition in China
NCMMW 2009
National Conference on Microwave and Millimeter Wave in China
May 23–26, 2009 • Xi'an, China
www.cnmw.org

JUNE

RFIC 2009
IEEE Radio Frequency Integrated Circuits Symposium
June 7–9, 2009 • Boston, MA
www.rfic2009.org

IMS 2009
IEEE MTT-S International Microwave Symposium
June 7–12, 2009 • Boston, MA
www.ims2009.org

EMC 2009/China
International Exhibition on Electromagnetic Compatibility
June 16–18, 2009 • Beijing, China
http://expo.ces.org.cn

China MW 2009
China Microwave 2009 Exhibition
June 16–18, 2009 • Beijing, China
http://chinamw2009.ces.org.cn

AUGUST

EMC 2009
IEEE International Symposium on Electromagnetic Compatibility
August 17–21, 2009 • Austin, TX
www.emc2009.org

SEPTEMBER

4G World 2009
September 14–18, 2009 • Chicago, IL
http://global.wimaxworld.com

EuMW 2009
European Microwave Week
September 28–October 2, 2009
Rome, Italy
www.eumweek.com

OCTOBER

RF & Hyper 2009
October 6–8, 2009 • Paris, France
www.rfhyper.com

AOC 2009
Association of Old Crows International Symposium and Convention
October 18–22, 2009 • Washington, DC
www.crows.org

NOVEMBER

AMTA 2009
Antenna Measurement Techniques Association
November 1–6, 2009 • Salt Lake City, UT
www.amta.org

COMCAS 2009
The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems
November 9–11, 2009 • Tel Aviv, Israel
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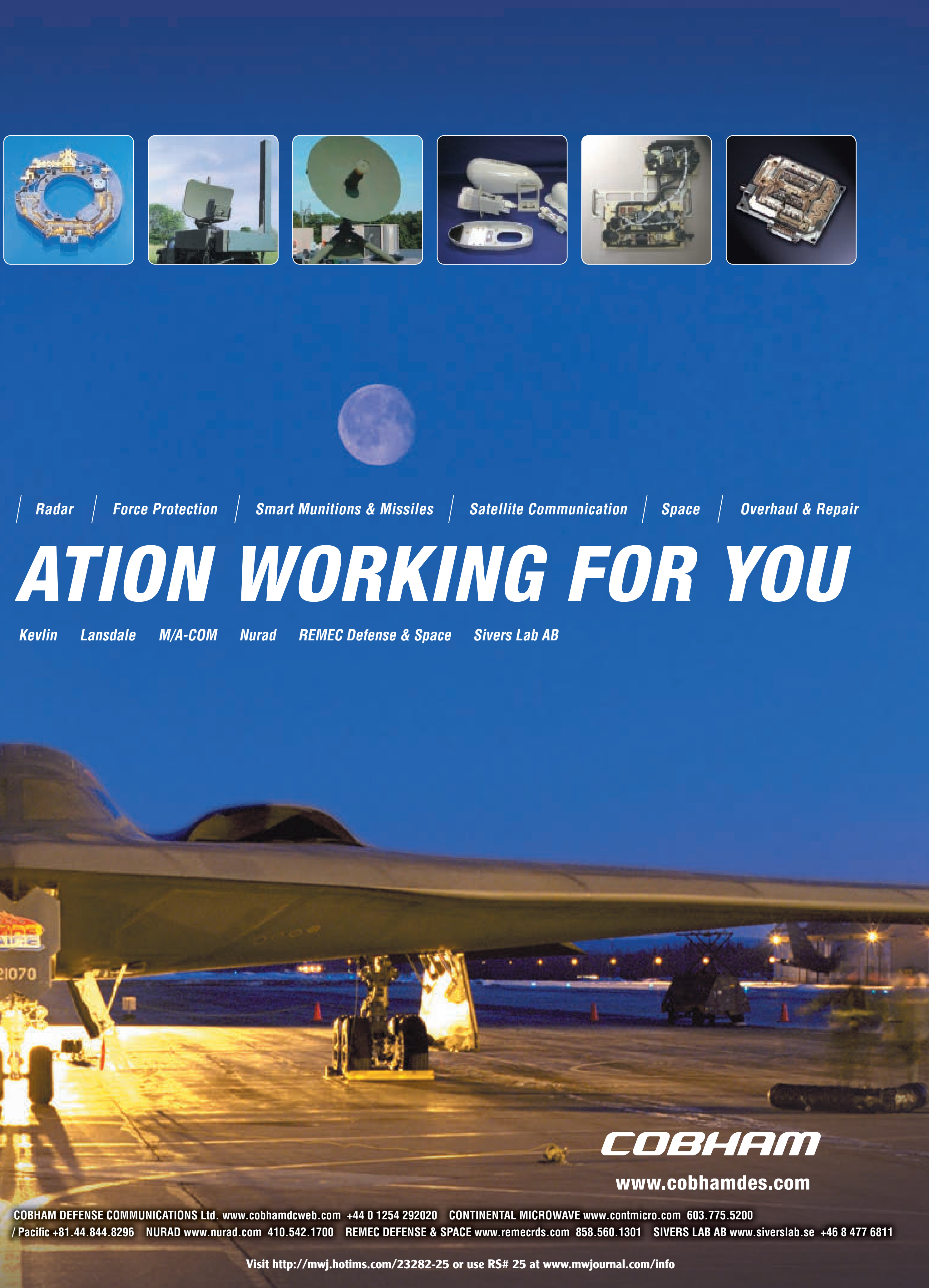

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COVER FEATURE

TEST SOLUTIONS SOUP UP FOR 4G

SEVERAL TEST AND MEASUREMENT EQUIPMENT VENDORS PROVIDED FEEDBACK TO *MWJ* EDITORS ON THE STATE OF TEST TECHNOLOGY AND THE NEEDS OF THE MARKET. READ THEIR RESPONSES AT WWW.MWJOURNAL.COM/4GTEST.

Characterization of digital communication systems and related RF hardware relies on complex test systems. These systems play a critical role in design and production performance evaluation. The building blocks of a digital communication system often require simultaneous time and frequency domain analyses, blurring the lines between the dedicated functions associated with traditional stand-alone scopes and analyzers. Designers must also investigate nonlinear behavior and the response to infrequent events. In turn, test and measurement equipment is evolving dramatically. Test equipment manufacturers are providing more capability by relying on the latest hardware and software for feature-rich and easy to use solutions with impressive raw performance. To understand how test equipment is evolving, *Microwave Journal* editors talked to representatives from Agilent Technologies, Anritsu, Keithley Instruments, Rohde & Schwarz and Tektronix. The following are some of their impressions on the state of RF test solutions in 2009.

TEST CHALLENGES

Release 7 of 3GPP has been designed as an upgrade for existing HSPA networks, and is sometimes called "HSPA+", or "evolved HSPA". The release introduces MIMO and 64QAM to increase data rate of the air interface. Beyond Release 7, 3GPP is now developing the standards for a new mobile network. Called Long Term Evolution (LTE) and System Architecture Evolution (SAE) for next generation mobile networks, this is the next step in the continuous move to wider bandwidth and higher data rates.

We asked several vendors to comment on how new technologies such as MIMO, LTE or DigRF were impacting RF and microwave testing. All agreed that the rapid pace of technology has required greater collaboration between vendors, chip set manufacturers and technical specification groups. Test solutions are more

DAVID VYE
Editor, Microwave Journal

comprehensive (integrated) than the single metric test equipment of the past. Software also plays a key role in providing functionality, up-to-date standards compliance and ease of use.

Roland Steffen of Rohde & Schwarz remarked that, "Compared with existing technologies such as WCDMA or GSM, standards such as LTE and HSPA+ place more stringent requirements on test and measurement equipment, due to more complex modulation methods (64QAM), multi-antenna systems (MIMO – multiple input, multiple output) and expanded layer-1 configuration capabilities. Processes are becoming more complicated in the protocols as well. Test equipment has to meet these requirements. Furthermore, LTE is a new technology, and the specifications are still evolving. A close working relationship between the test equipment vendor, wireless device manufacturers and chipset designers is required to synchronize feature implementation, reference specifications and timely delivery of the test equipment software."

One example of this occurred last September when Rohde & Schwarz and Beceem Communications Inc. announced their collaboration to provide a custom test solution for Beceem's mobile WiMAX chipsets. The goal of this partnership was to provide a fast, easy-to-handle test solution for all WiMAX equipment manufacturers using Beceem chipsets. The R&S CMW270 WiMAX communication tester provided the all-in-one solution with a continuous frequency range for all WiMAX band classes up to 6 GHz, real-time signaling, a VSA for transmitter verification and VSG for expanded receiver testing. This single box unit was demonstrated with the Beceem chipset at this past year's WiMAX World in Chicago, IL. Test time optimization was given priority in the CMW270 platform architecture. Multi-evaluation measurements and parallel Tx/Rx test algorithms reduced chipset configuration and handling times. Internal switching between RF channels further improved RF calibration of multi-antenna devices (MIMO) by eliminating external adaptation. The unit also demonstrated a non-signaling mode for RF alignment in production and a signaling mode (base station emulation) for testing under simulated network conditions.

For analyzing MIMO and LTE signals, Rohde & Schwarz's signal analyzers (R&S FSQ, R&S FSG as well as R&S FSV models) enable detailed testing of the physical layer. The signal analyzers can be equipped with options for LTE and MIMO allowing simultaneous processing of signals transmitted by the multiple antennas. They can also be used to determine whether pre-coding for LTE signals works across the different stages. R&D engineers can observe the performance of both the baseband and RF bands. The analysis software also ensures that engineers, developers and technicians can respond quickly to new developments of the standard.

R&S also noted that it has added MIMO pre-coding and channel coding to its LTE signal generators. The company has demonstrated a 2x2 MIMO receiver test using its R&S SMU200A RF signal generator as a one-box solution, already including real time fading capability. For baseband testing, the R&S AMU200A baseband generator and fading simulator is available. The combination supports MIMO test for LTE, WiMAX, WLAN and HSPA+.

▲ *Fig. 1 Rohde & Schwarz CMW500 wideband radio communication tester.*

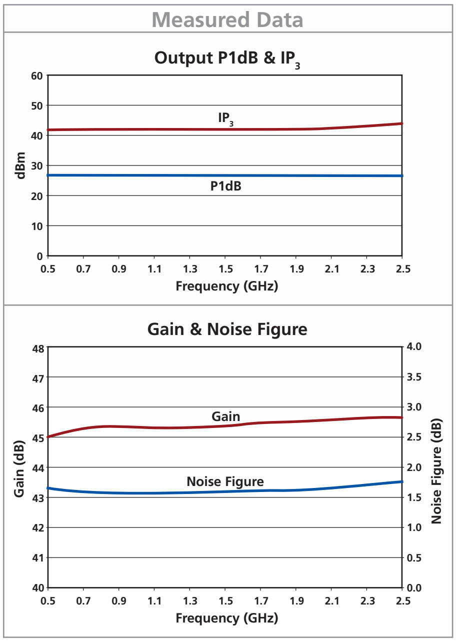
In addition to its existing RF portfolio, Rohde & Schwarz unveiled its initial solution for protocol tests (layer 1 to layer 3) for 3GPP LTE at last year's Mobile World Congress in Barcelona, Spain. The R&S CMW500 (see ***Figure 1***) for LTE and HSPA+ protocol tests offers multiple interfaces for communicating with the protocol layers to be tested in the wireless device (DUT). Depending on the DUT's level of integration, a purely software interface, a digital I/Q interface or an RF interface can be used. Tests carried out with the RF interface require a protocol implementation that has been fully integrated into the baseband and the RF. The interface used is transparent for the protocol layers above and the tester's software modules. The user can therefore switch between interfaces without having to modify test routines and software tools.

Carla Feldman, Wireless Business Unit Marketing Manager at Agilent Technologies, responded to our question by stating that, "There is no doubt that both 3GPP LTE and WiMAX have, and will continue to have, a significant and lasting impact on the communications industry in 2009. R&D spending in LTE, for example, has already begun ramping up from chipset development to components and integrated hardware. The same can be said of the technologies that go into making a LTE system work such as MIMO and DigRF V4—the latest version of the DigRF electronics interface standard for the cellular market."

Feldman used the complexity of MIMO technology to illustrate Agilent's solution to one particular test challenge. "(To) ensure this technology's optimal operation requires the engineer to accurately test the MIMO receiver—a challenging task given the large combination of variables that must be tested in a given MIMO configuration. A critical part of testing a MIMO receiver is replicating real-world conditions and channels and performing real-time fading of MIMO signals. Agilent's PXB MIMO Receiver Tester provides up to 4 baseband generators, 8 faders, 120 MHz bandwidth, custom MIMO correlation settings, and supports testing and troubleshooting of 2x2, 2x4 and 4x2 MIMO. Signal Studio signal creation software runs in the instrument and provides the engineer with up-to-date standards-compliant signal creation."

The Agilent PXB (see ***Figure 2***) is a recent advance in MIMO receiver testing marrying the signal source, noise source and fader together in a fully-integrated solution to successfully accomplish these tasks. Rather

High Linearity LNAs



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- ***I/O return loss of 11 dB min***
- ***Gain of 35 dB or more***
- ***Low power dissipation***
- ***Optional gain/phase matching***
- ***Stable performance -54°C to +85°C***

Model	Frequency Range GHz	Gain dB Min	Gain Flatness +/- dB Max	Noise Figure dB Max	Output P1dB dBm Min	OIP_3 dBm Min	VSWR In & Out Max	DC Current @ +12 to +15VDC mA Typ	Package Type
JCA02-4000	0.5 to 2.0	40	1.00	1.8	24	40	1.8:1	450	K4
JCA24-4001	2.0 to 4.0	35	1.25	2.0	24	40	1.8:1	450	K4
JCA48-4000	4.0 to 8.0	35	1.50	2.2	24	40	1.8:1	450	K4

OPTIONS

Variable Gain Control	TTL Switching	Temperature Compensation
Input/Output Isolators	Waveguide Interface	Detector Output
Input Limiters	Phase Tracking	Gain Matching
Limiting Amplifiers	Low Phase Noise	Hermetic Packages
Environmental Screening	K-Connectors	Bias-T Output

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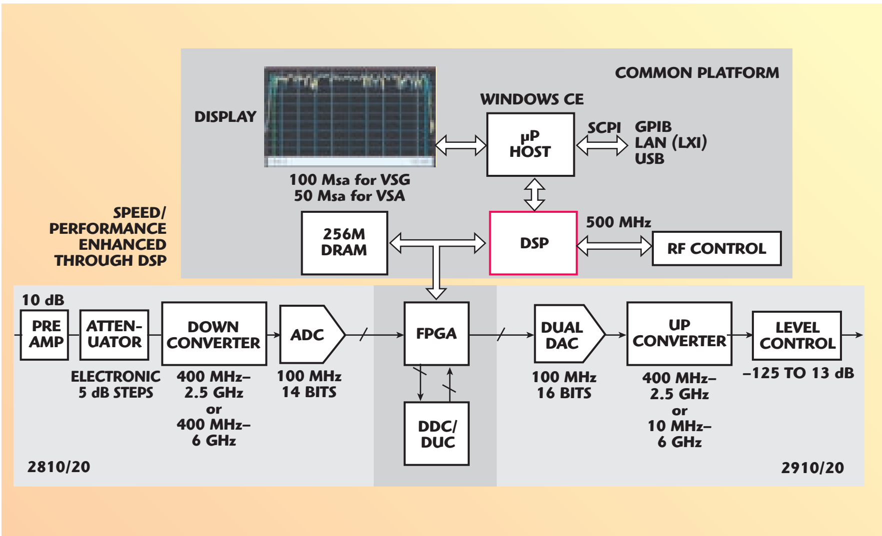
than offering signal generation only, this measurement approach offers an exceptionally versatile platform for testing LTE and WiMAX receivers. It not only allows the engineer to replicate real-world MIMO conditions and channels, but also to generate realistic fading scenarios including path and channel correlations.

With regard to DigRF, Feldman noted that, "Agilent recently introduced the industry's first Digital Radio Frequency (DigRF) V4 test solution. It enables comprehensive stimulus and analysis for developers of radio-frequency integrated circuits (RFIC) and baseband ICs as well as integrators of wireless handsets. 'Cross-domain' test, such as DigRF V4, offers new insights that reach from individual digital bits all the way through to IQ-modulated RF signals. Agilent's test solution allows engineers to work in the domain (digital or RF) and abstraction level (physical or protocol layers) of their choice to quickly characterize RFICs and rapidly solve cross-domain integration problems."

Engineers at Keithley Instruments pointed out that, "LTE and WiMAX both use the same underlying technology—OFDM (orthogonal frequency-division multiplexing) and MIMO. While this has some advantages, in terms of similar radio architectures and the ability to interchange product development engineers easily between the two types of technology, a number of differences must be considered. Base stations offer the highest opportunity for a common platform, since the cost, size and power requirements are far different from the handset, or "user equipment." A common 20 MHz IF can be employed, combined with the multiple RF systems required for the different transmission bands specified for WiMAX and LTE and the multiple streams required for a MIMO transmission. A handset presents a number of challenges because cost, size and power performance are critical for market acceptance. LTE has been optimized for power amplifier efficiency transmitting SC-TDMA; while a WiMAX UE transmits OFDM, which requires a higher cost and more power-hungry amplifier, it has a smaller signal processing footprint.

With respect to test, two approaches could be used. It's possible to measure the products to the documented specifications. The software-defined radio architecture in instruments such as the Keithley Model 2820 RF Vector Signal Analyzer and Model 2920 Vector Signal Generator fully support standards-based test for both LTE and WiMAX, using a single hardware platform (see ***Figure 3***). Or, one can take

▲ *Fig. 2 Agilent's N5106A PXB MIMO receiver tester.*



▲ *Fig. 3 Block diagram showing digital circuit in the model 2820 VSA and 2920 VSG.*

advantage of the power of this type of test equipment architecture and characterize the RF performance in terms of magnitude and phase quality. This would provide a generic way to derive specifications such as WiMAX or LTE modulation quality. When MIMO comes into play, one will need a generic indication of the isolation between each RF module or unit as well. The test equipment needs to cover the required frequency range and transmission bandwidth, such as a frequency range of 400 MHz to 6 GHz with a bandwidth of 20 MHz. If it's necessary to add WLAN (802.11n) into the architecture, 40 MHz of bandwidth would be required. This approach may provide very fast test times and a higher utilization of test equipment, but it requires an investment in time and resources to be able to verify that the product meets both its regulatory and interoperability requirements."

Anritsu Co. supports HSPA+, LTE, MIMO and DigRF through flexible cost-effective solutions that take advantage of customers' existing investments, an important aspect in today's market, according to Wade Hulon, Vice President and General Manager of Anritsu's Americas Sales and Marketing.

"In our present economic environment, companies must walk the tightrope of continuing to develop 4G products while controlling costs. Our test platforms allow customers to easily integrate hardware and software so they can address emerging technologies such as LTE, MIMO and DigRF," said Hulon.

The MS269xA Series is an example of that philosophy. The company recently introduced three software packages for the signal analyzers to address LTE testing: the MX269020A LTE downlink measurement software, the MX269021A uplink measurement software and the MX269908A LTE IQ producer. Last October, Anritsu introduced a test platform consisting of the MS269xA equipped with a vector signal generator, a DigRF interface and measurement software. As a single-instrument alternative to existing DigRF test systems, the platform reduced bench space, cost, and time to accurately evaluate transmit and receive performance of DigRF RFICs.

LTE support is also provided by Anritsu's MD8430A, the first LTE base station simulator. The MD8430A allows manufacturers of LTE chipsets and mobile devices to quickly, accurately and cost-effectively evaluate their products and improve time to market. The MD8430A can be used with the MF6900A, a fading simulator, to create an LTE physical layer and protocol test solution.

Additionally, the MD8430A (see ***Figure 4***) can be combined with Anritsu's MD8480C W-CDMA Signalling Tester and used for the simulation of both W-CDMA/HSPA/HSPA Evolution and GSM/GPRS/EGPRS base stations. This combination supports LTE-UTRAN/GERAN Inter-RAT handover tests and maximizes customers' investments in existing hardware. The MD8480C, along with the MT8820B Radio Communications Analyzer, MS269xA and MG3700A Vector Signal Generator, all support the evolution of HSPA Release 7, including 64QAM and MIMO.

ADVANCES IN TEST EQUIPMENT

We asked vendors what they felt was among their most significant new products and technologies and how it was impacting test and design. Several of the manufacturers pointed to advances in raw performance, speed, upper-frequency range and display technology as key enablers to more capable testing. Among these advances, recent improvements in fast triggering, digitizer performance and deep memory are also making oscilloscopes a powerful tool for studying how components respond to wideband signals.

DIGITAL OSCILLOSCOPES

Agilent's Carla Feldman remarked that, "RF engineers are increasingly using oscilloscopes in addition to signal analyzers for analyzing both the

▲ *Fig. 4 Anritsu MD8430A LTE base station simulator.*

growing digital content in their radio designs along with direct radio signal analysis especially in the emerging ultra-wideband (UWB) measurements. Technologies such as wireless USB, pulsed radar, WiMedia, '60 GHz' UWB and other UWB technologies can couple the native wideband capabilities of an oscilloscope with vector signal analyzer software for powerful modulation domain measurements. We address this market opportunity by coupling our low noise (high dynamic range) oscilloscopes, the industry's deepest memory and our powerful 89601A VSA Software."

Software provides the functionality and versatility for today's test equipment to maintain compliance with evolving standards and to improve engineering productivity. The Infiniium supports the installation of third-party software packages on the Windows XP Pro operating system such as Excel, LabVIEW, Agilent VEE, MATLAB and anti-virus software. Test engineers can perform customized processing and automation. In addition, Agilent recently announced the U7239A MB-OFDM PHY test software, which automatically configures the Infiniium 90000 oscilloscope for each test and generates an informative HTML report at the end of the test. It compares the results with the specification test limit and indicates how closely the device passes or fails each test. The complex analysis runs seamlessly within the scope, which saves users time and effort compared to making and analyzing measurements manually.

Agilent's DSO/DSA 90000A family of oscilloscopes introduced in March 2008 offers industry-leading noise performance along with the first ever 1 GB deep memory to a family of high performance oscilloscopes having bandwidths from 2.5 to 13 GHz. According to Agilent, these scopes offer a low noise floor (147 µVrms at 5 mV per division - 2.5 GHz model), deep memory, fast hardware trigger system, fast off-load speed (remote), large front-panel display and fast measurement speed. All these features are designed to provide engineers with better insight through superior signal integrity and debugging capability.

By providing ever larger amounts of acquisition memory, engineers are able to capture an ultra-long record of signals, such as 25 ms of signal data at 40 Giga-Samples per second (GS/s). Using deep memory with peak detect allows engineers to capture infrequent glitches. MegaZoom III is the third generation of the fast and deep memory architecture introduced by Agilent in 1996. It combines fast, responsive deep memory with a high-resolution display system to make it easier for engineers to find elusive signal anomalies. The new InfiniiScan Plus event identification system is based on the fastest hardware trigger system. This new trigger system can identify glitches faster than 250 ps. Infiniium 90000A will offer the only three-level trigger system, combining multiple hardware triggers with the InfiniiScan software, providing virtually infinite trigger combinations for any debug situation. Applications include DDR, PCIe, DisplayPort, HDMI, Serial ATA, Serial Attached SCSI, Ethernet families, USB, wireless USB, jitter analysis, RF signal analysis, eye pattern analysis and protocol decoding analysis.

Darren McCarthy, Technical Marketing Manager of Tektronix, was in agreement, commenting that "Sampling technology now extends to 50 GS/s with real-time bandwidths to 20 GHz. The oscilloscope technology has enabled faster high-speed serial data designs and the discovery of the true high-frequency behavior of fast rise-time phenomena. These advances allow scopes to address the wireless design market and ultra-wideband technologies from RFID to satellite. Synthetic aperture radar (SAR) is also a developing market that can directly take advantage of current oscilloscope technology with direct measurements thru to the Ku-band."

With the recent introduction of the DPO/DPO70000B series digital oscilloscopes in January 2009, Tektronix offers some impressive performance with regard to vertical resolution (ENOB) and wide bandwidth real-time oscilloscopes. The integration of the SignalVu™ software turns the real-time oscilloscope into a high performance wideband spectrum analyzer. The user interface is designed to allow simple control of frequency, span, resolution bandwidth and acquisition time. The software is integrated

directly to the acquisition engine of the oscilloscope, which enables the analysis engine to utilize the entire memory for measurements. McCarthy claims, "This gives the user the best frequency, time resolution and capture depth available for wideband signal analysis."

SPECTRUM ANALYZERS

McCarthy feels that the patented real-time technology from Tektronix, which includes the display, trigger and streaming technology would "radically change how spectrum analyzers are used in development and field operations. The DPX™ Live RF spectrum technology available across the company's entire portfolio from field portable to high-performance benchtop spectrum analyzers is 100s to 1000s of times faster than previously available spectrum trace technology and enables engineers to see signals-within-signals and find spectrum anomalies that have never been seen (see ***Figure 5***). It is not just about finding what might be wrong with a transmitter, but also providing the confidence that a design is done properly when the behavior shows no anomalies."

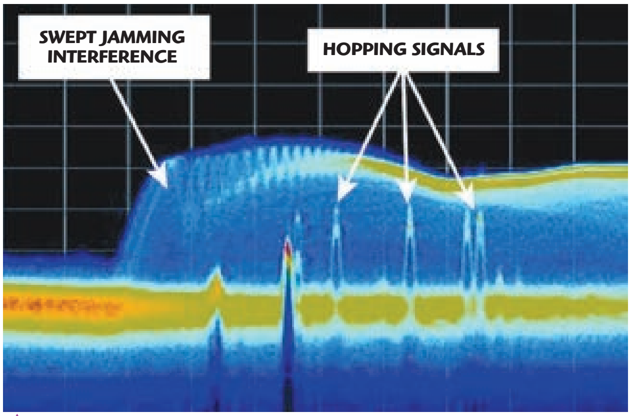
Another real-time technology pointed out by McCarthy "is the unique Frequency Mask Triggering, which enables the efficient isolation of transient spectrum events when traditional level or event triggers won't work. With efficient event isolation, engineers have reduced troubleshooting time and have often found the frequency selective triggering as the only solution to reliably validate designs.

Tektronix's real-time digital outputs are also unique on spectrum analyzers. When combined with commercially available data recording systems, this has enabled real-time spectrum analyzers to be used for critical field monitoring applications when all signals need to be collected in the spectrum. Using commercial off-the-shelf spectrum analyzers for mission critical applications, such as real-time data collection, reduces operational expense and improves uptime while providing the flexibility to analyze, trigger, and mark signals of interest as they are recorded."

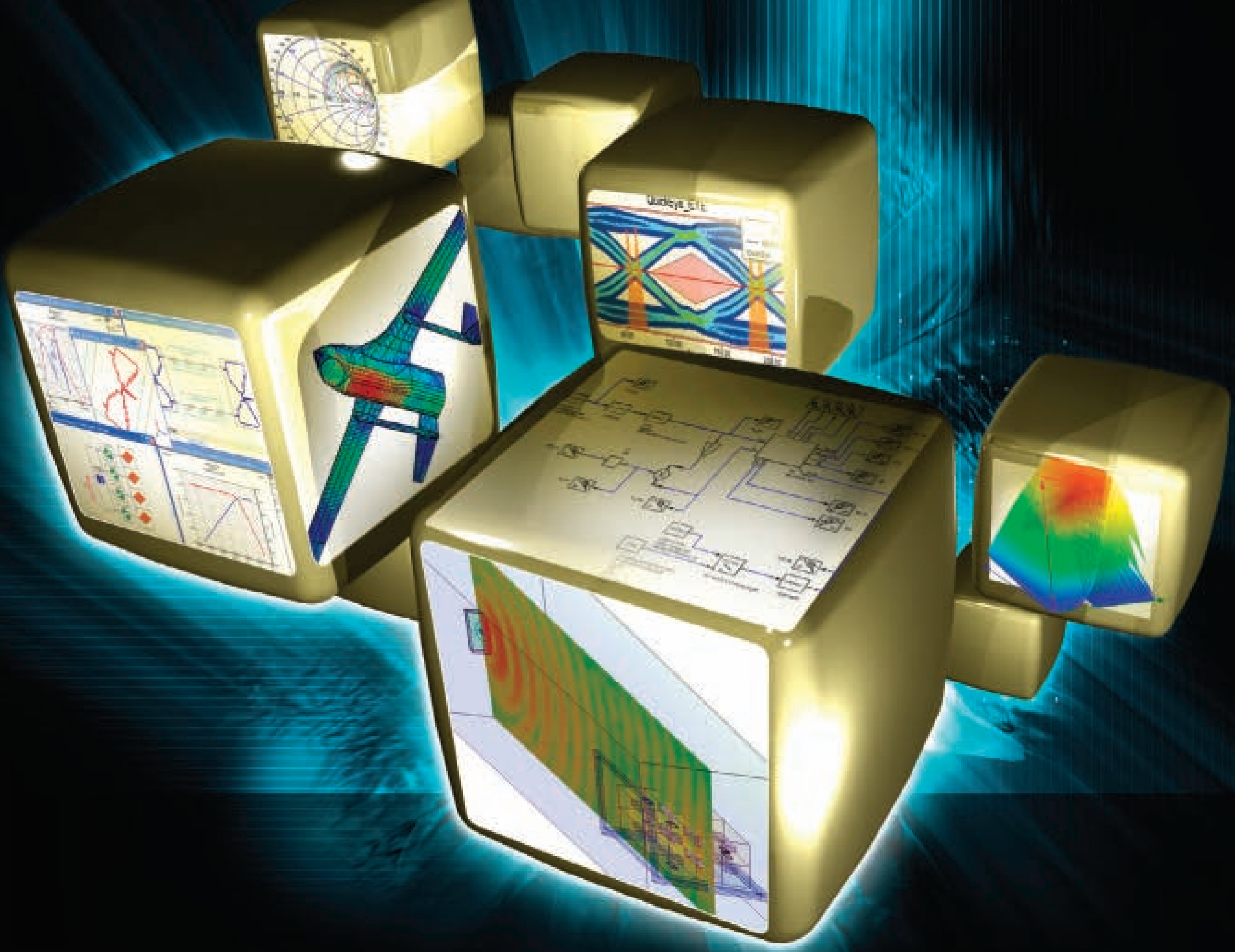
When asked about the importance of speed in test today, several vendors offered examples of where speed was critical and what set the standard today. Steffen of R&S commented on the importance of speed to help address intense price competition among wireless equipment manufacturers by allowing them to reduce production and test costs. "For these users, faster measurement speed is necessary to attain shorter test cycles and the best price for a given performance level. The R&S FSV signal and spectrum analyzer and the SMBV vector signal generator, for example, are designed specifically for speed and design considerations." The R&S FSV is capable of up to 500 sweep repetitions in manual operation and up to 1000 in remote operation. "This high sweep rate is important for more than just production applications. Whenever accurate and repeatable power measurements require averaging, or when a certain number of averages is required by a standard specification, this sweep rate will allow development engineers to achieve their results in a much shorter time."

COMMUNICATION TESTER

Many wireless devices now combine multiple radio technologies such as GSM, WCDMA, Bluetooth, WLAN and GPS while also operating



▲ *Fig. 5 DPX™ Live RF spectrum technology locates signals-within-signals and random spectral events.*



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at the high data rates required for mobile Internet. Many devices must also operate in multiple frequency bands and support multimode operation to support mobile radio service on any continent; as a result testing has become time-consuming and costly.

Rohde & Schwarz has developed a special approach to saving time and costs in production. Utilizing the R&S Smart Alignment test concept, the R&S CMW500 wideband radio communication tester makes alignment times up to ten times faster than with conventional methods. Plus, the tester is optionally equipped with two channels, which allows parallel measurement of two DUTs using different standards. Since a maximum first pass yield is necessary in order to achieve minimum production costs, high standards were placed on absolute accuracy, repeatability and linearity during the development of the tester.

Keithley felt that its SignalMeister™ RF Communications Test Toolkit was among their most significant new products of the past year. This next-generation software tool allows engineers to create and analyze the complex signals used in the most advanced wireless transmission protocols. It generates and analyzes both single-input, single output (SISO) signals and MIMO signals used in the latest versions of the WLAN and WiMAX protocol standards. In addition to creating high quality signals, the SignalMeister RF Communications Test Toolkit can create impairments to model non-ideal transmitter conditions and real channel conditions such as fading and noise.

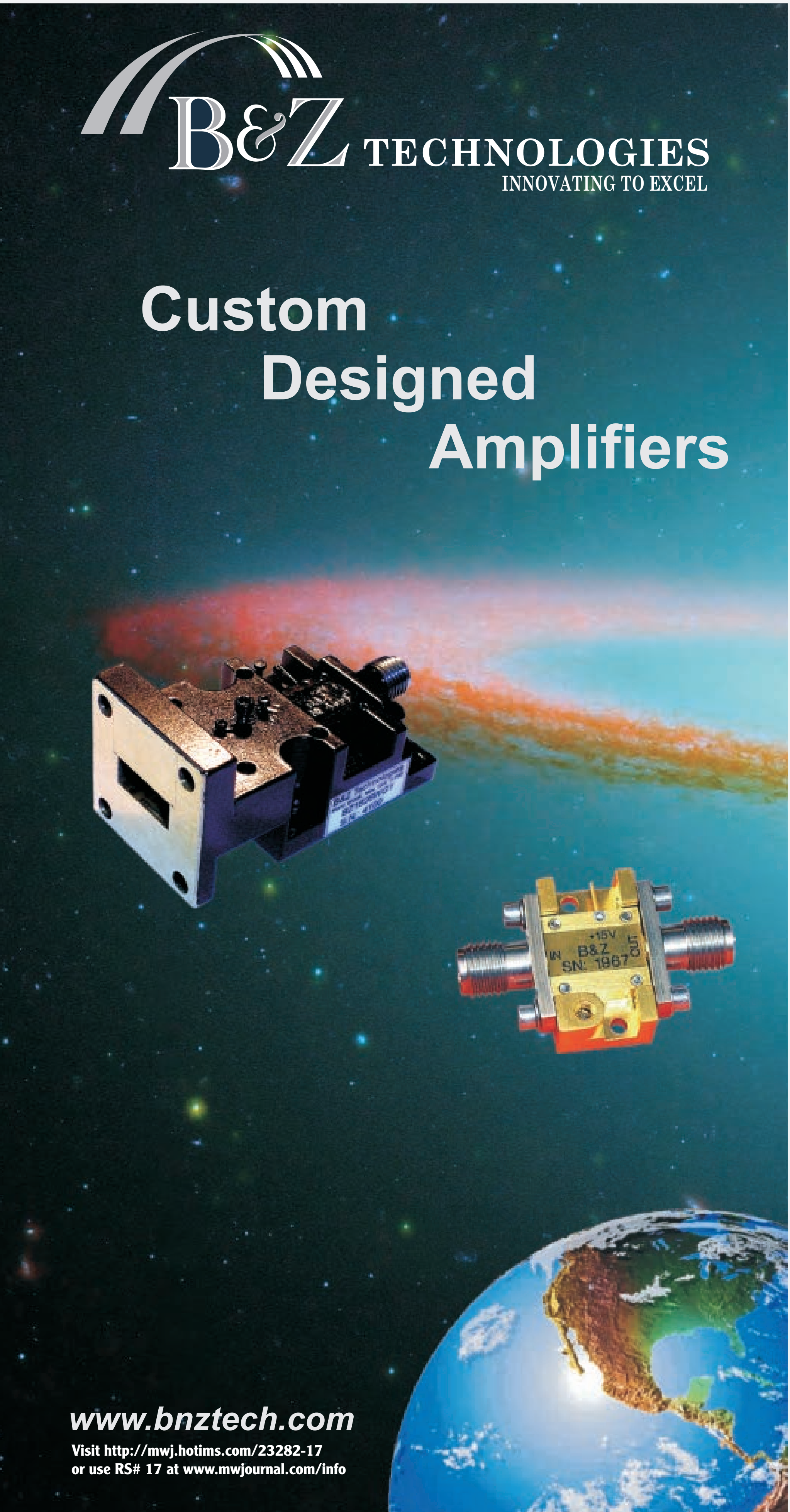
The SignalMeister software has the unique ability to analyze the transmitted signals, acquiring and demodulating the signals, then computing and displaying a wide range of parametric data. In addition, the SignalMeister toolkit can perform simulation studies without the need to use the actual hardware, which allows researchers and designers to study the impact of transmitter impairments and channel effects on signal transmissions easily. This powerful software platform integrates the signal creation libraries of multiple wireless communication standards into a single package. The built-in toolset can be used to modify all signal types, including non-encrypted waveform files produced by other software packages, to support extensive product testing.

NETWORK ANALYZERS

Agilent wanted to discuss its ongoing development of the Nonlinear Vector Network Analyzer (NVNA) and X-parameters. New software for use with the PNA-X microwave network analyzer provides linear measurements, but can easily switch into the NVNA mode for nonlinear measurements. Agilent recently introduced new Nonlinear Vector Network Analysis capability featuring a breakthrough in X-parameters (new, nonlinear scattering parameters) that now allows engineers to quickly and accurately design and develop linear components and subsystems by removing the trial and error loops. The 802.16 standard on which Mobile WiMAX is based specifies a tight Error Vector Magnitude (EVM) requirement (–31 dB, based on a 1 percent packet error rate). Meeting this target requires that all system blocks be more linear and phase noise be considerably better than in an 802.11 design. Power amplifiers must also be more linear and boast higher efficiency. The key to developing linear active devices for LTE or Mobile WiMAX-based systems is to first characterize the nonlinear behaviors—those that do not have a linear input/output relation and are a major contributor to information interference and the reduction in effective bandwidth.

Anritsu Co. recently introduced the VectorStar™ premium series of microwave VNAs, offered in three standard frequency ranges that go to 20, 40 and 70 GHz. The MS4640A delivers frequency coverage of 70 kHz to 70 GHz, dynamic range of 103 dB at 67 GHz and measurement speed of 20 µs/point.

For true broadband applications such as device modeling, the 70 kHz low-end provides seven octaves of additional information below the traditional 10 MHz cut-off of conventional microwave VNAs. This improves the error-prone task of DC-approximation, providing better device models and circuit simulation. The low-end frequency also improves stability as it eliminates coupler roll-off below 1 GHz.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VectorStar's 100 dB dynamic range at 70 GHz creates accuracy never before seen in a microwave VNA, according to Anritsu. Supplementing the wide dynamic range is the MS4640A's excellent receiver compression level. The VNA's receiver has a +10 dBm 0.1 dB compression level at 70 GHz. With the new Precision AutoCal for 70 kHz to 40 GHz or 70 GHz calibrations, residual directivity of 42 dB can be achieved at 70 GHz, and up to 50 dB at 20 GHz.

LOOKING AHEAD

We ended our conversation with these test equipment vendors by asking, "How is technology improving the capabilities of test equipment?"

Rohde & Schwarz remarked that, "Wireless devices evolve more and more into multi-standard platforms. Therefore, wireless device manufacturers need T&M equipment that supports all important cellular and non-cellular standards. In general, T&M equipment manufacturers are expected to be able to implement new trends in their products very quickly in order to provide the flexibility customers demand. That's why a key aspect today is the capability to upgrade T&M products by means of software—when new standards require higher data rates, for instance. Rohde & Schwarz develops test instruments that easily accommodate such changes. There's no need to buy or develop a new box —just perform a software update.

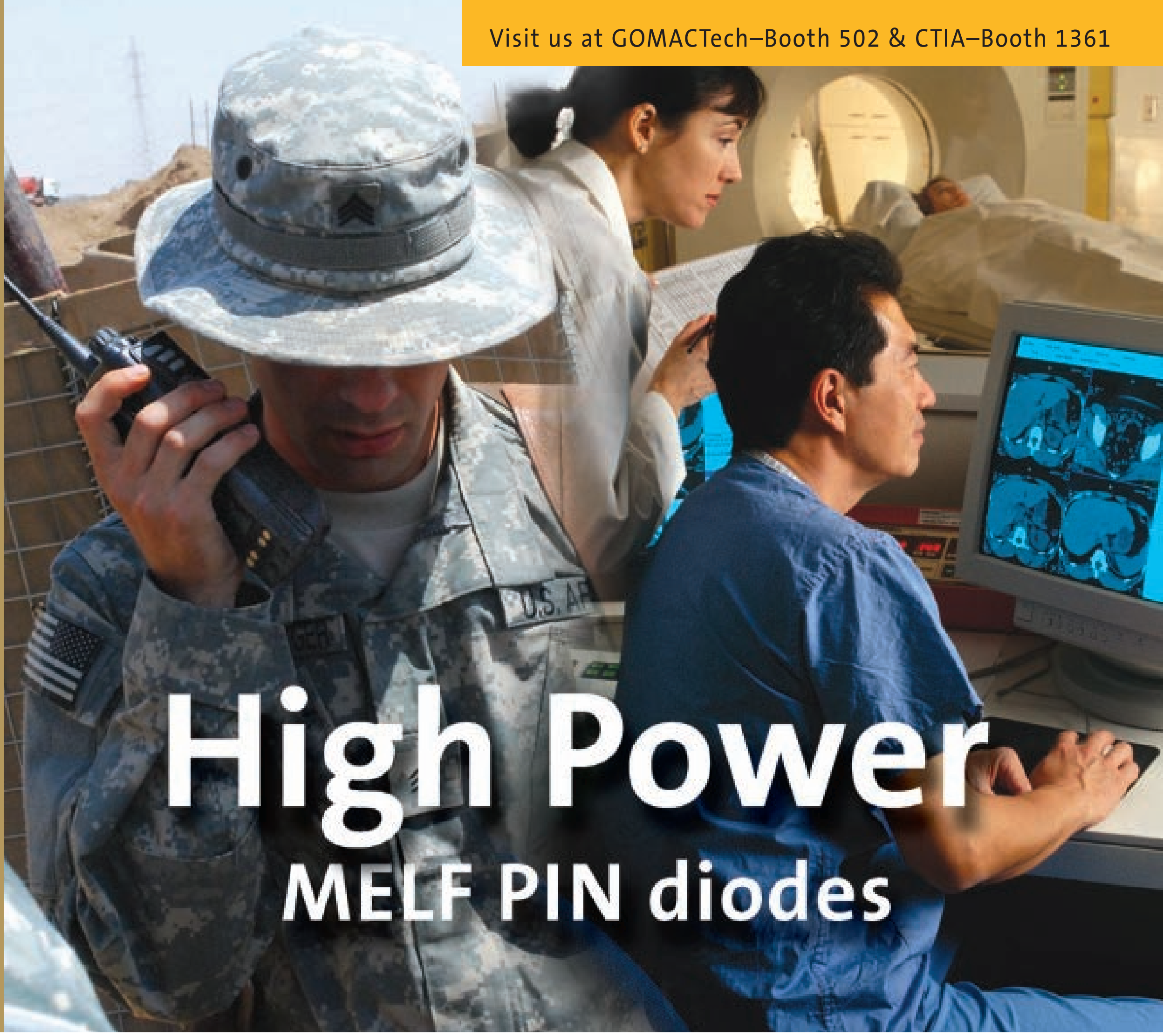
Since the 1950s, the consumer electronics industry, from radios to mobile phones, has experienced a tenfold increase in the upper frequency limit around every 20 years. Modern digital standards such as WiMAX, LTE and WLAN 802.11n or vehicle distance radar are advancing this development. It won't be long before the 100 GHz boundary for user applications is exceeded. In anticipation of this trend, test equipment must be prepared to serve customers as they step up to very high frequencies."

Keithley concurred: "The rapid development of new wireless communication standards requires an almost constant re-evaluation of the sourcing and measurement capabilities needed for wireless device research and production testing. One way in which test equipment vendors have risen to address this customer need is to design instruments that are more flexible. New technologies like software-defined radio (SDR) architectures let vendors design instruments that are flexible and adaptable to the changing needs of the industry.

The essence of an SDR implementation is that the modulation and demodulation functions performed on RF signals are done by digitizing the signals and using software and processing techniques, rather than dedicated hardware. This approach allows transmitting or receiving a wide variety of signals more economically than with dedicated, modulation-specific hardware.

The basic principle of software-defined radio is to replace analog circuitry with digital circuitry that can be programmed via software. Functions that were traditionally done in analog hardware, such as frequency generation and conversion, modulation and demodulation, and filtering, are performed with digital hardware. SDR designs also include unique digital functions that can improve the performance of the radio. These functions include decimation and interpolation, which can extend the dynamic range of the radio, and waveform pre-distortion, which can improve the modulation accuracy. In the case of waveform pre-distortion, the modulating signals are modified from the ideal signal to counteract known analog distortion characteristics."

Agilent noted that, "Many of the same technologies that drive the need for new measurement solutions for our customers are also used by Agilent in the design of our latest test and measurement products. For example, the trend from parallel to serial buses in order to achieve higher system throughput is embodied in our latest oscilloscope products, which use multiple serial data lanes to transmit data from the A/D converters to the memory management system. The continued developments in ASIC technologies are routinely capitalized upon in creating our products. And advancements in simulation technologies are used by our engineers in designing our equipment. Besides allowing us to create our solutions, the fact that we are using the new technologies ourselves enables us to directly identify with the key challenges facing our customers." ■



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- Low distortion vs. forward current — optimal for stringent attenuator applications
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MA4PH235-1072T	35	0.5	1.2	15
MA4P1450-1091T	50	0.75	2.5	5
* MA4P1250-1072T	50	0.75	1.5	15
* MA4P4001F-1091T	100	0.5	2.2	5
* MA4P7101F-1072T	100	0.5	1	15
MA4P7001F-1072T	100	0.8	0.7	15.5
MA4P4301F-1091T	100	1	2	8
MA4P4002F-1091T	200	0.5	2.2	6.5
MA4P7102F-1079T	200	0.5	1	21
MA4PH237-1079T	200	0.6	1.5	25
MA4P7002F-1072T	200	0.8	0.7	15
MA4PH236-1072T	200	3	0.5	25
MA4P7104F-1072T	400	0.5	1	20
MA4P506-1072T	500	0.3	1	10
MA4P505-1072T	500	0.45	0.65	15
MA4P504-1072T	500	0.6	0.5	20
* MA4P4006F-1091T	600	0.5	2.2	6
* MA4P7006F-1072T	600	0.8	0.7	13

* Non-magnetic equivalents available

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Lockheed Martin Testing Advanced EHF Military Communications Satellite

Lockheed Martin announced that the second Advanced Extremely High Frequency (EHF) military communications satellite is now undergoing thermal vacuum testing at the company's Sunnyvale, CA facilities. The US Air Force's Advanced EHF system will provide global, highly secure, protected, survivable communications for warfighters operating on ground, sea and air platforms. One of the most significant program milestones, thermal vacuum testing will verify Advanced EHF spacecraft functionality and performance in a vacuum environment where the satellite is stressed at the extreme hot and cold temperatures it will experience in space throughout its 14-year design life.

Advanced EHF thermal vacuum testing is conducted in Lockheed Martin's Dual Entry Large Thermal Altitude (DELTA) chamber and is one of several critical environmental test phases that validate the overall satellite design, quality of workmanship and survivability during space vehicle launching and on-orbit operations. "The start of this critical environmental test is another important milestone in our development of this sophisticated protected communications program," said John Miyamoto, Lockheed Martin's Advanced EHF vice president. "Our team is focused on executing a highly disciplined and successful test, demonstrating with high confidence that the spacecraft will meet all performance requirements."

Following completion of spacecraft thermal vacuum testing, the team of Lockheed Martin Space Systems, the Advanced EHF prime contractor, and Northrop Grumman Aerospace Systems, Redondo Beach, CA, the payload supplier, will perform environmental test data analysis and remaining integration and test activities necessary to prepare the vehicle for flight. The spacecraft is planned for delivery to the Air Force in 2011 in preparation for launch aboard an Atlas V launch vehicle.

A single Advanced EHF satellite will provide greater total capacity than the entire Milstar constellation currently on-orbit. Individual user data rates will be five times improved. The higher data rates will permit transmission of tactical military communications, such as real-time video, battlefield maps and targeting data. In addition to its tactical mission, Advanced EHF will also provide the critical survivable, protected and endurable communications to the National Command Authority including presidential conferencing in all levels of conflict. Lockheed Martin is currently under contract to provide three Advanced EHF satellites and the Mission Control Segment to its customer, the Military Satellite Communications Systems Wing, located at the Space and Missile Systems Center, Los Angeles Air Force Base, CA. The program is in the early stages of adding a fourth spacecraft to the planned constellation.

Northrop Grumman Awarded US Navy Contract for Shipboard Interrogator Sets

Northrop Grumman has been awarded a $16 M contract from the US Navy for production of five additional AN/UPX-24(V) interrogator sets for the US Navy and the Australian Navy. The AN/UPX-24(V) is a shipboard identification-friend-or-foe (IFF) processor system that is used to identify aircraft or ships equipped with an IFF transponder. The system provides target data to the ship's command, control, communications, computer and intelligence (C4I) system and generates interrogation commands in response to requests for priority target identification. The AN/UPX-24(V) accepts interrogation and control commands and provides target reports to a shipboard weapon system, such as Aegis or the Naval Tactical Data System.

"The AN/UPX-24(V) IFF interrogator set is a sophisticated air defense system that provides the fleet with a long range early warning system for target detection," said Ike Song, vice president of situational awareness systems at Northrop Grumman's Navigation Systems Division. "The AN/UPX-24(V) protects sailors in the fleet by rapidly and accurately identifying an aircraft."

Deliveries for this 22-month fiscal year 2008 contract are scheduled to begin in February 2010 and consist of five full AN/UPX-24(V) interrogator sets with remote control indicators and nine retrofit kits for installation on current systems. More than 90 AN/UPX-24(V) systems have been delivered by Northrop Grumman for the US Navy and for international navies. The new FY08 production systems will be installed on board the Nimitz-class carrier USS Theodore Roosevelt (CVN 71) and the first of the new Gerald R. Ford-class carriers, CVN 78. Northrop Grumman's IFF product line offerings also include the AN/UPX-39 family of single channel or dual channel interrogators, which can replace aging IFF interrogators that can no longer be maintained. Built with modern, digital commercial-off-the-shelf equipment this product can be used for both military and civil applications. The AN/UPX-39 family meets Federal Aviation Administration, Department of Defense, North Atlantic Treaty Organization (NATO), and International Civil Aviation Organization (ICAO) standards. It also complies with Air Traffic Control Radar Beacon IFF Mark XII Systems (AIMS) and Eurocontrol requirements for identification and air traffic control systems and it supports operating mode 1, 2, 3 and 4, mode A, B, C, D and mode S, with a growth path for Mode 5.

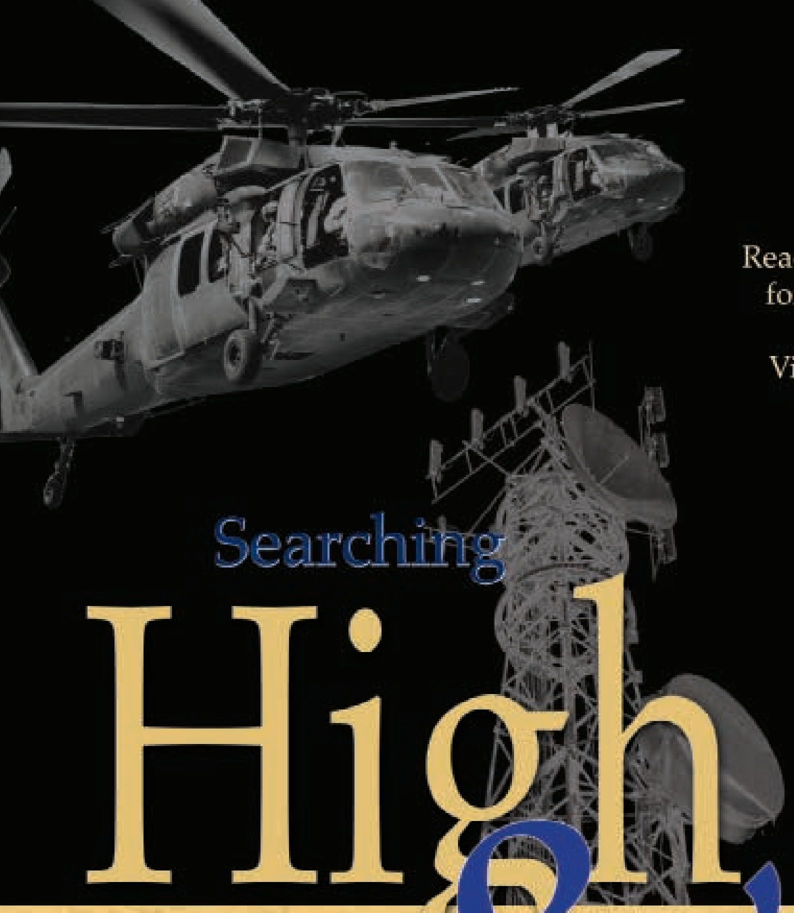
Upgraded Early Warning Radar in Greenland Achieves Satellite Tracking

Raytheon Co.'s Upgraded Early Warning Radar (UEWR) at Thule Air Base, Greenland, has achieved a significant milestone on its path toward operational status, successfully tracking its first satellite in an operational space surveillance mission configuration. "It is impressive that this event was accomplished after only 31 hours of test time that sets a new record for bringing a UEWR system to the first track milestone," said Pete Franklin, vice president of National and Theater Security Programs for Raytheon Integrated Defense Systems. "Upgrading the UEWR will provide increased capability for missile defense."

As the prime contractor, Raytheon is integrating new leading-edge electronics, computer hardware and mission software that upgrades the existing two-faced, phased-array antenna facility at the remote site and adds capability to support missile defense missions. Raytheon, awarded the Thule UEWR contract in April 2006, will support integrated tests of the Thule UEWR, performing missile defense, early warning and space surveillance missions. Developed by Raytheon, the UEWR continues the company's heritage of Ultra High Frequency phased-array radars. The UEWRs add missile defense capabilities to the Raytheon-developed PAVE PAWS and Ballistic Missile Early Warning System radars, while continuing their missile warning and space surveillance missions for the US Air Force Space Command. The radar is a key sensor for the Missile Defense Agency's Ballistic Missile Defense System, providing target detection and tracking to protect the US and other nations from ballistic missile attacks.

Raytheon Wins Contract to Develop Next-generation Jammer Technology

The US Navy has awarded Raytheon Co. a $5.5 M contract for a technology maturation study of next-generation jammer capability. The Next Generation Jammer program will support the Navy's airborne electronic attack requirements by developing innovative ways of tactical jamming against current and future threats from the EA-18G aircraft as the target platform. Under the contract, Raytheon will use its unique combination of multi-beam jamming techniques and antenna array technology to investigate the effectiveness of alternative next-generation jamming solutions. "Effective airborne electronic attack requires electromagnetic spectrum dominance in the air and on the ground," said Roy Azevedo, deputy vice president for Raytheon's Tactical Airborne Systems mission area. "This study will provide a vital foundation for the development of a more robust open-architecture jammer with greater spectral precision, power, reactive speed and directivity. The expected improvements in availability and lower life-cycle costs will ensure a viable future capability for naval electronic warfare." Work on the study is being done by the company's Space and Airborne Systems business. ■



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20 - 115 MHz, minimum	≥ 40 dB @ 150 MHz & ≥ 50 dB @ 250 - 600 MHz
20 - 150 MHz, minimum	≥ 40 dB @ 200 MHz & ≥ 50 dB @ 300 - 600 MHz
20 - 220 MHz, minimum	≥ 40 dB @ 300 MHz & ≥ 50 dB @ 450 - 900 MHz
20 - 335 MHz, minimum	≥ 40 dB @ 440 MHz & ≥ 50 dB @ 660 - 1400 MHz
20 - 500 MHz, minimum	≥ 35 dB @ 670 MHz & ≥ 50 dB @ 1005 - 2000 MHz
20 - 700 MHz, minimum	≥ 40 dB @ 980 MHz & ≥ 50 dB @ 1470 - 2000 MHz
20 - 1010 MHz, minimum	≥ 35 dB @ 1400 MHz & ≥ 50 dB @ 2100 - 3000 MHz
20 - 1400 MHz, minimum	≥ 40 dB @ 2000 MHz & ≥ 50 dB @ 3000 - 4200 MHz
20 - 2000 MHz, minimum	≥ 40 dB @ 2800 MHz & ≥ 50 dB @ 4200 - 5000 MHz
20 - 3000 MHz, minimum	≥ 40 dB @ 3940 MHz & ≥ 50 dB @ 5910 - 6000 MHz

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Philips and VTT Open Development Centre in Finland

Royal Philips Electronics and VTT have opened an InnoHub in the city of Espoo, close to Helsinki to generate innovative ideas and translate these into profitable businesses. The two companies have an equal role in the cooperation. The InnoHub is situated in the Active Life Village (a non-profit company catalyzing innovations). This enables easy access to experts in other innovation organizations in the same building as well to the whole region, supporting strongly an open innovation environment concept.

It is envisaged as a one-stop shop for the entire innovation process, from generating ideas, to concept development, prototyping and testing of products and services. The real-life setting enables testing of products between various locations and stakeholders. Both multinational companies and SMEs can engage with the InnoHub's experts and support services. All Nordic and Baltic companies are able to tap into Philips' and VTT's innovation experience for entire innovation projects as well as additional specialist support in certain phases of a project that has already started.

The innovation process steps will be executed in short-cycles. The insights of the various specialists operating in the different stages of the innovation process will be continuously fed back to the parties involved. InnoHub is focused on tangible deliverables that can be tested on their performance. By doing so, every specialist will be challenged to show the added value of his or her contribution, to confront others with their own constraints, and to cope with the limitations of others. This kind of result-oriented approach also leads to respect for each others' disciplines in a learning organization.

Companies can benefit from the InnoHub by becoming members and paying a yearly contribution to obtain services or by commissioning ad-hoc projects. User-centric development and end-user validation testing prior to product release will help companies to reduce the time to market, development costs and field call rates. Current discussions concern projects on interconnectivity of products and services and a number of SMEs have shown an interest in conducting part of their innovation work in the InnoHub.

ESA and EC Extend GMES Agreement

The European Space Agency (ESA) Director General, Jean-Jacques Dordain, and the Director General of the European Commission's Directorate General for Enterprise and Industry, Heinz Zourek, have signed an amendment to the EC-ESA Global Monitoring for Environment and Security (GMES) agreement that will extend the scope of the original Agreement (signed in February 2008) to activities of Segment 2 of the GMES Space Component Programme. This paves the way to ordering the second units of the Sentinel 1, 2, 3 satellites as well as the atmospheric chemistry missions Sentinel 4 and 5 precursor.

Segment 2 of the GMES Space Component (GSC) Programme, which will span the period 2009-2018, overlapping with the ongoing Segment 1 (2006-2013), will complete the development of the initial five new Sentinel satellites, developed by ESA specifically to meet the needs of GMES, and will ensure operational access to Earth observation data from Contributing Missions for the user community.

Segment 2 was approved by the ESA Member States at the last ESA Ministerial Council meeting held in November 2008 with subscriptions to the programme from ESA Participating States amounting to €831.4 M (at 2008 economic conditions). The new amendment adds a further contribution from the European Commission of €205 M to Segment 2 of the GSC programme.

Saab Opens Office in India

Saab's investment in India is continuing with the opening of an office in New Delhi, which will support the company in its efforts to market products for defence and civil security in the Indian market. Saab is committed to providing its cutting-edge technologies across air, land and sea.

The company is also endeavouring to reduce manufacturing and production costs by developing, designing and manufacturing state-of-the-art defence and civil security systems in India. To that end, the country will become a key manufacturing hub for Saab in the near future and the company is in advanced discussions with a number of Indian companies in the public and private sector.

Jan Widerström, vice president, Saab International, stated, "The goal is to make use of the great knowledge and resource bank available in the country. We plan to offer a first class life cycle support, through our local partners and cut costs for our global market."

e2v Centre for Electronic Imaging Opens for Business

The Open University and e2v will open the e2v Centre for Electronic Imaging (CEI) at The Open University's Milton Keynes, UK, campus. The centre will be dedicated to the research and development of advanced technologies for electronic image sensing and provide knowledge exchange between the UK technology industry and the academic world.

e2v is a world leader in the design and supply of image sensors to organisations such as NASA (e.g. for the 2009 upgrade of the Hubble Space Telescope), whilst The Open University's Planetary and Space Science Department (PSSRI) is a world leader in the development of instrumentation for Space Science (e.g. lead the Beagle-2 lander and was lead group for the Surface Science package on ESA's Huygens probe).

The collaboration will see the two parties investing £3 M in the UK knowledge economy over five years in new research activity through the centre. Its joint research centre will focus on the development of technology opportunities in space and terrestrial imaging, with plans to extend the scope to health and environmental applications.

Andrew Holland, professor of electro-optics with The Open University, says the collaboration will provide long-term benefits to science, training and the creation of world-leading intellectual property. "Both academic research and the development of industrial technology require highly skilled researchers with a thorough understanding of the needs of industry. The e2v Centre for Electronic Imaging will provide an avenue for doctoral students and research staff to explore routes to industrial advancements for business sustainability, and technological breakthroughs in science and medicine."

SONS and Authors: New NGMN Alliance Document

The Next Generation Mobile Network (NGMN) Alliance has released a document that outlines the requirements for self-optimising networks (SON). In order to provide overall guidance on solutions supporting SONs for the future, the new document provides several use cases and identifies requirements of operators aiming to implement SONs.

SONs offer key operational and financial benefits for operators thinking of investing in next generation networks. Future networks must be dynamic and have the ability to adapt to user requirements. Self-optimising networks are capable of reconfiguring themselves for maximum operational efficiency, which in turn significantly reduces the total cost of ownership of a network.

Self-optimising networks are seen as having a key role in the future proofing of network reliability and operational efficiency. In order to set out a framework for achieving these objectives the NGMN document focuses on the key issues such as SON enablers, self-configuration, self-optimisation, fault management and fault correction and O&M related SON. ■

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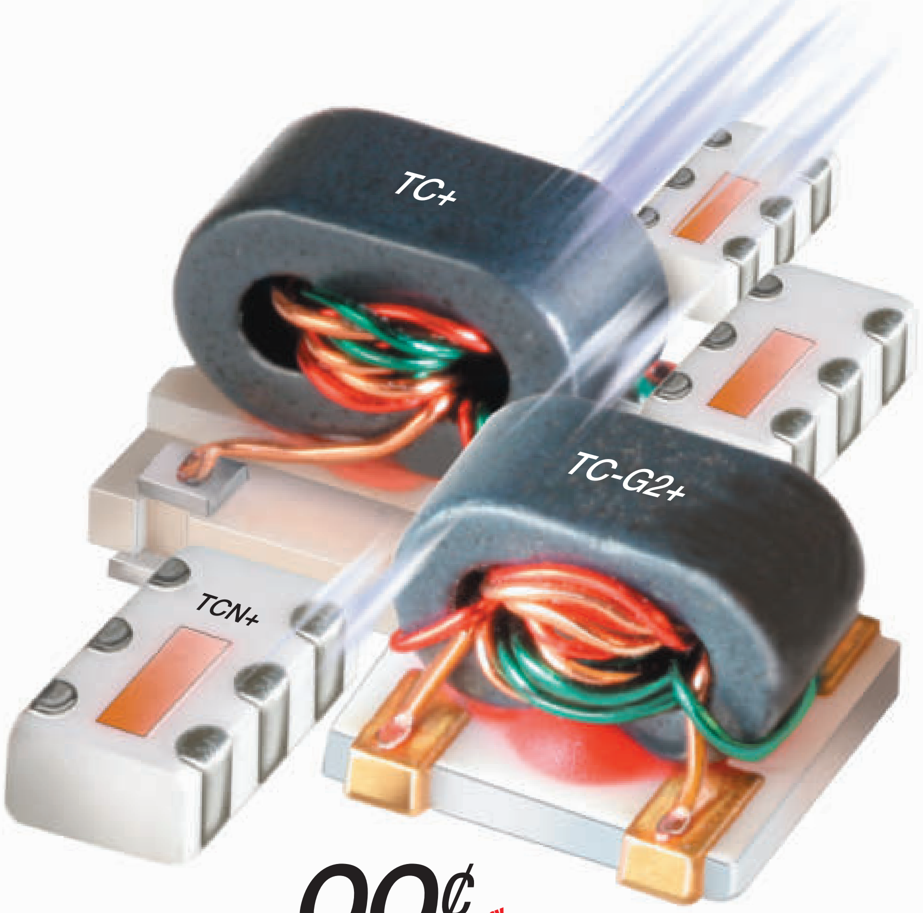

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IEEE Commemorates 125 Years of Engineering the Future

IEEE, the world's largest technical professional society, is commemorating its 125^{th} Anniversary this year with a variety of activities surrounding the theme of "Celebrating 125 Years of Engineering the Future." Major anniversary events include the first IEEE Presidents' Change the World Competition for college and university students worldwide; a global media roundtable and webcast addressing emerging, world changing technologies; a series of celebrations in major world cities throughout the year; and IEEE Engineering the Future Day on 13 May 2009. The latest information is available on the new anniversary web site: www.ieee125.org.

IEEE traces its roots to the founding of the American Institute of Electrical Engineers by early industry giants, including Thomas Alva Edison and Alexander Graham Bell. Today's global IEEE has become a trusted source for fostering technological innovation and excellence for the benefit of humanity as well as the profession. "For the last 125 years, IEEE has fostered technological innovations that have helped improve the quality of life," said 2009 IEEE president John Vig. "We are proud of our heritage and our community where the best in engineering, technology and applied sciences continue to learn, discover and develop new knowledge for the benefit of humanity worldwide."

IEEE kicked off its celebration on 1 September 2008 with the launch of its first Presidents' Change the World Competition. The goal of the contest is to recognize and reward individual college and university students or teams of students who identify a real-world problem and apply engineering, science, computing and leadership skills to solve it. Winners will be announced in June at the IEEE Honors Ceremony in Los Angeles, CA. For more information, visit www.ieee125.org/ChangeTheWorld.

To ensure that IEEE members, media, members of the technology industry and the general public have a one-stop resource for everything related to the 125^{th} Anniversary, IEEE has launched an anniversary web site, www.ieee125.org. The web site provides up-to-date information on anniversary activities and includes a calendar of events; a press room and multimedia center with videos, photos and message boards; a viral video contest; and a toolkit to help IEEE members plan their own anniversary events. On 10 March 2009, IEEE held a media roundtable in New York City, NY. Notable researchers in human technology interactions highlighted emerging technologies that have world-changing implications. The goal of the event was to celebrate IEEE's 125^{th} Anniversary, and to facilitate an open dialogue among media and respected names in the engineering and technology sectors. The event also provided a platform to promote IEEE's Engineering the Future Day, on 13 May, the actual anniversary date of IEEE. Through events and activities, this occasion will help increase awareness of technology advancements around the world. These are just a few of the anniversary events planned globally throughout 2009. Visit the anniversary web site at www.ieee125.org for more information.

Cell Phone Industry Faces Unprecedented Challenges in 2009

After 25 years of stellar growth, the cell phone (also known as mobile phone) industry faces huge challenges this year from a poor economy and a lack of new features, reports In-Stat. The bleak cell phone industry outlook is unprecedented, with dramatic ramifications for device manufacturers, semiconductor manufacturers and mobile operators alike. "While the cell phone industry has generally been unaffected by economic ups and downs, the near future is different," says Allen Nogee, In-Stat analyst. "The current economic slowdown is more widespread and deeper than ever experienced during the cell phone's lifetime, and has spread through Europe, Asia and North America. In addition, this is the first year without any new major features being added, and last year's new feature, mobile TV, has only become popular in limited regions."

Recent research by In-Stat found the following:

- Over 1.2 billon cell phones were estimated to have shipped in 2008, but the growth rate is plummeting.
- For the next five years, cell phone semiconductor revenue will only grow at a 3.3 percent Compound Annual Growth Rate (CAGR).
- Shipments of dual-mode cellular/Wi-Fi phones shipped will quadruple from 2008 to 2012.
- The market for digital baseband semiconductors in WCDMA handsets will reach more than $6 B annually in 2012.
- In 2008, cell phone semiconductor revenue was expected to reach more than $44.5 B, up over 6.2% over 2007.

The research, "A Tarnished Silver Anniversary for Handsets—Worldwide Handset and Semiconductor Forecast," covers the worldwide market for cellular handsets and semiconductors. It provides a comprehensive view and five-year forecasts of:

- Cell phone shipments and revenue
- Cell phone semiconductor revenue
- Segmentation by region and technology (TD-SCDMA, LTE, WCDMA, CDMA, GSM)
- Segmentation by device type (ICs & Discretes, Power amplifier, Radio, Memory, Apps processor, analog and digital baseband)
- Feature & attach rates forecasts of WLAN, Over-the-Air Tuners, Bluetooth, Cameras, CCD and CMOS Image sensors, and GPS
- Deep analysis of semiconductor and handset trends

For more information on this research or to purchase it online, please visit: http://www.instat.com.

Dual Mode Cellular/ Wi-Fi Handset Shipments to Double from 2008 Through 2010

Shipments of Wi-Fi-enabled cellular handsets will double in volume by the end of 2010, compared to January 2008, and that growth curve is expected to continue through 2013. This data, contained in a new ABI Research study, shows how driven by increasing consumer awareness and demand, new operator business models, and increased value for handset manufacturers, Wi-Fi technology will continue to penetrate deeper into mobile handsets over the next five years.

Industry Analyst Michael Morgan comments, “This past year there has been an explosion of Wi-Fi capable phones. Due to operator and customer demand, and handset manufacturers trying to deliver more product value, Wi-Fi is quickly becoming ‘table stakes’ for smartphones.” The user’s experience appears to be critical in handset Wi-Fi adoption. While Nokia leads the market in Wi-Fi-enabled handsets due to the sheer volume of its portfolio, Wi-Fi models only represent a small fraction of the range. In contrast, every Apple iPhone has Wi-Fi, and due to its ease of use and the seamless iTunes experience, more iPhone users—as many as 75 percent—are using their Wi-Fi regularly. Contrasting again, HTC’s handset lineup is 80 percent Wi-Fi-equipped, but only 10 percent of its users are employing the Wi-Fi capability.

Despite the rosy outlook, Morgan cautions, there are challenges to Wi-Fi’s growth. “One obstacle is the glacial pace of IEEE standardization in the areas that address voice over Wi-Fi usage. Another is the growing carrier interest in femtocells. While they have their problems, femtocells do provide an alternative to improving in-building coverage without the need for Wi-Fi capable handsets. Although Wi-Fi access points are already installed in many homes and business, the carriers may ultimately push to have femtocells installed at these key locations.” In Wi-Fi’s favor: as flat rate data plans increase, wireless operators can leverage Wi-Fi capable handsets to offload data intensive applications, improve in-building coverage and offer new services to new markets.

The new ABI Research study, “Wi-Fi Capable Handsets,” examines the market opportunities and provides forecasts for Wi-Fi from a handset-based perspective, focusing on drivers, barriers and competing technologies. It forms part of three ABI Research Services: Wi-Fi, Business Mobility and Mobile Devices. ■

INDUSTRY NEWS

■ **AWR**, a leader in high frequency electronic design automation (EDA), announced it has acquired **Simulation Technology and Applied Research Inc.** (STAAR), Mequon, WI, a developer of 3D parallelized FEM tools for EM simulation of components and subsystems operating at RF and microwave frequencies. STAAR is now a wholly-owned subsidiary of AWR Corp., retaining its operations and facilities in Wisconsin, and under the continued guidance of STAAR founder John DeFord.

■ **Paratek** and **STMicroelectronics** have entered into a strategic relationship to supply RF tunable products to mobile wireless markets. The two companies have been cooperating to advance the next generation of Paratek's ParaScan™ materials technology for high volume manufacturing and to jointly develop tunable products that improve Total Radiated Power (TRP) for mobile phones, leading to longer battery life and fewer dropped calls. Initial production will take place at STMicroelectronics' fabrication facility in Tours, France by the end of 2009.

■ **Skyworks Solutions Inc.**, an innovator of high performance analog and mixed signal semiconductors enabling mobile connectivity, and **Ember**, a leader in ZigBee® technology, announced that they are partnering to develop the industry's first portfolio of ZigBee front-end modules (FEM) targeting applications such as smart meters in energy management, home area networks (HAN) and industrial automation. ZigBee is a wireless network standard that solves the unique needs of remote monitoring and control, and sensor-network applications.

■ **Fastrax**, a supplier of high performance GPS receivers, GPS software solutions and tracking systems for location-aware devices, and **SiGe Semiconductor**, a global supplier of products that are enabling wireless multimedia in a wide variety of computing, entertainment and mobile systems, announced that Fastrax has selected SiGe's SE4120 to power its Software GPS solution. As a result of the collaboration, the Fastrax Software GPS and SiGe Semiconductor's SE4120 radio front-end makes available a high performance GPS solution, complimented with a reference design to enable easy integration by third parties.

■ **Leader Tech** announced the completion of its Phase II, Global EMI Shielding Technology Center expansion. Since the grand opening announcement in May of 2008, Leader Tech has benefited from a notable increase in demand for the company's board-level EMI Shielding products. The most recent expansion includes the addition of three domestic sales representatives, a new regional sales engineer and a dedicated 45-press manufacturing line.

■ **IEEE**, the world's largest technical professional society, is commemorating its 125th anniversary this year with a variety of activities surrounding the theme of "Celebrating 125 Years of Engineering the Future." Major anniversary events include the first IEEE Presidents' Change the World Competition for college and university students worldwide; and a global media roundtable and Webcast addressing emerging, world changing technologies.

■ **Times Microwave Systems** has recently obtained AS9100 Registration, an enhanced derivative of the ISO9001:2000 Standard. The AS9100 Standard was developed by the global commercial aerospace manufacturers (Boeing, EADS, UTC, CFM and GE) to incorporate all of ISO9001:2000 Standard, and expand the scope to address aerospace industry issues.

■ **PurecoatNorth LLC** recently announced that the company has received its National Aerospace & Defense Contractors Accreditation Program (Nadcap) approval for Aerospace Quality System (AC7004) and Chemical Processing. They are expecting that this will create a new source for customers requiring special processing of precious and non-precious, electroless and non-electroless plating.

■ **HRL Laboratories LLC** announced it has become a charter member of the Semiconductor Industry Association (SIA), the premier association representing the US semiconductor industry.

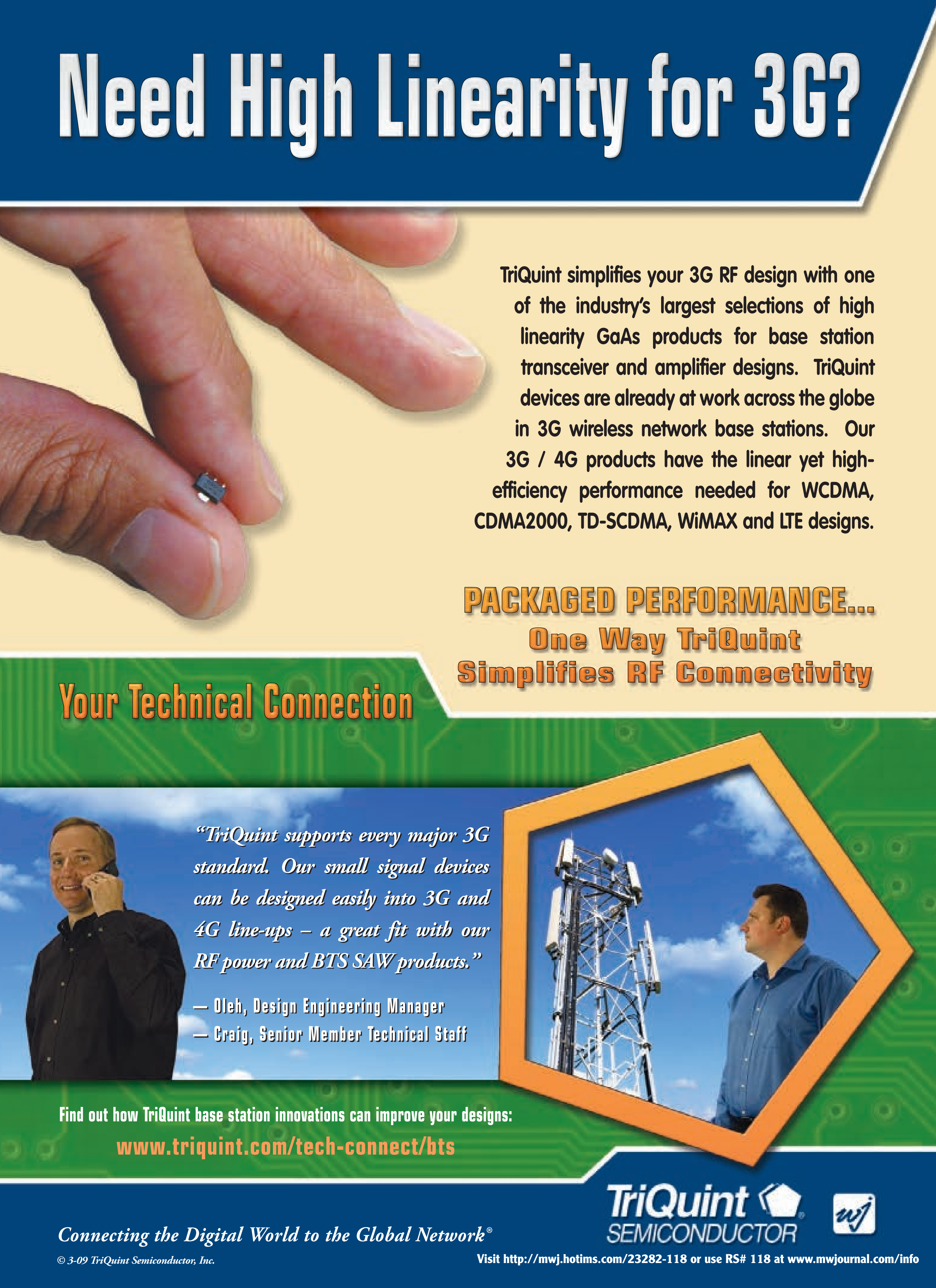
■ **W.L. Gore & Associates Inc.**, maker of GORE-TEX® fabric and thousands of other products, has announced it has earned a position on FORTUNE magazine's annual list of the "100 Best Companies to Work For" for the 12th consecutive year. Gore is ranked No. 15.

CONTRACTS

■ **L-3 Electron Technologies Inc.** (L-3 ETI) announced that it has received combined orders totaling nearly $1 M for the development of a high efficiency (> 50 percent) 600 W Ka-band communications helix traveling wave tube (TWT). The orders, which will help enhance US Air Force airborne platform communications technology, were placed by two US Air Force Research Laboratory (AFRL) contractors.

■ **Sypris Test & Measurement Inc.**, a subsidiary of Sypris Solutions Inc., and **Hi-Rel Laboratories Inc.** have signed a Joint Services Contract that provides for a single point of contact for customers seeking component testing and qualification services. The partnership benefits customers by offering combined expertise as well as a shared history of more than 70 years of reliable performance with semiconductor and passive component testing services.

■ **Intercept Technology Inc.**, a leader in PCB/hybrid/RF electrical engineering applications, announced that **National Instruments** has selected the Pantheon and Mozaix RF design flow on high performance RF designs. Intercept welcomes National Instruments, a leader in test and embedded measurements, to its community of users as a major technology collaborator. Intercept worked closely with National Instruments on the migration of in-process RF designs and the training of RF design and layout personnel in the Intercept user flow.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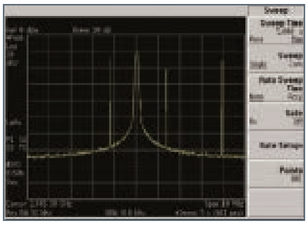
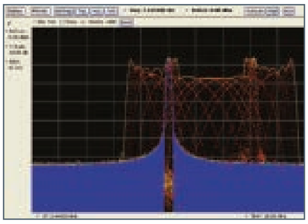
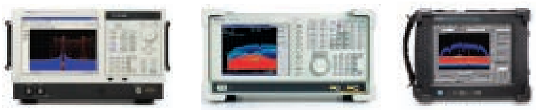






■ **DragonWave Inc.**, a supplier of high capacity, wireless native Ethernet backhaul solutions for mobile and access networks, announced that **ECAS Telecommunications & Systems Ltd.** has selected the Horizon Compact for Internet Protocol (IP) backhaul of WiMAX, 3.5G, Evolution Data Only (EVDO) and Long-Term Evolution (LTE) services in Nigeria. ECAS selected the DragonWave solution for its tremendous throughput, easy deployment and use and low power consumption.

PERSONNEL

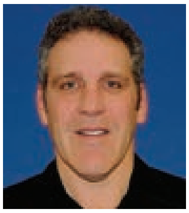
■ ANADIGICS Inc., a provider of semiconductor solutions in the broadband wireless and wireline communications markets, announced the appointment of **Mario Rivas** as president and chief executive officer. Gilles Delfassy, who has served the company as interim CEO since August 2008, will continue as chairman of the board. Rivas most recently served as CEO of Quartics, a fabless semiconductor and software company based in Irvine, CA. Prior to that, he was a senior executive at AMD where he led the computing solutions group.

▲ *Mario Rivas*

■ The Supervisory Board of LPKF Laser & Electronics AG has appointed **Ingo Bretthauer** as the new chief executive office of LPKF AG effective immediately. Alongside the current members of the Board of managing directors, Bernd Lange and Kai Bentz, Bretthauer will in particular push ahead the global sales of all LPKF products. Bretthauer has a broad experience in sales and marketing of industrial equipment. He previously worked seven years in various positions at AEG. He moved from AEG to Deutsche Bahn, where his last position was chief marketing officer at DB Reise & Touristik.

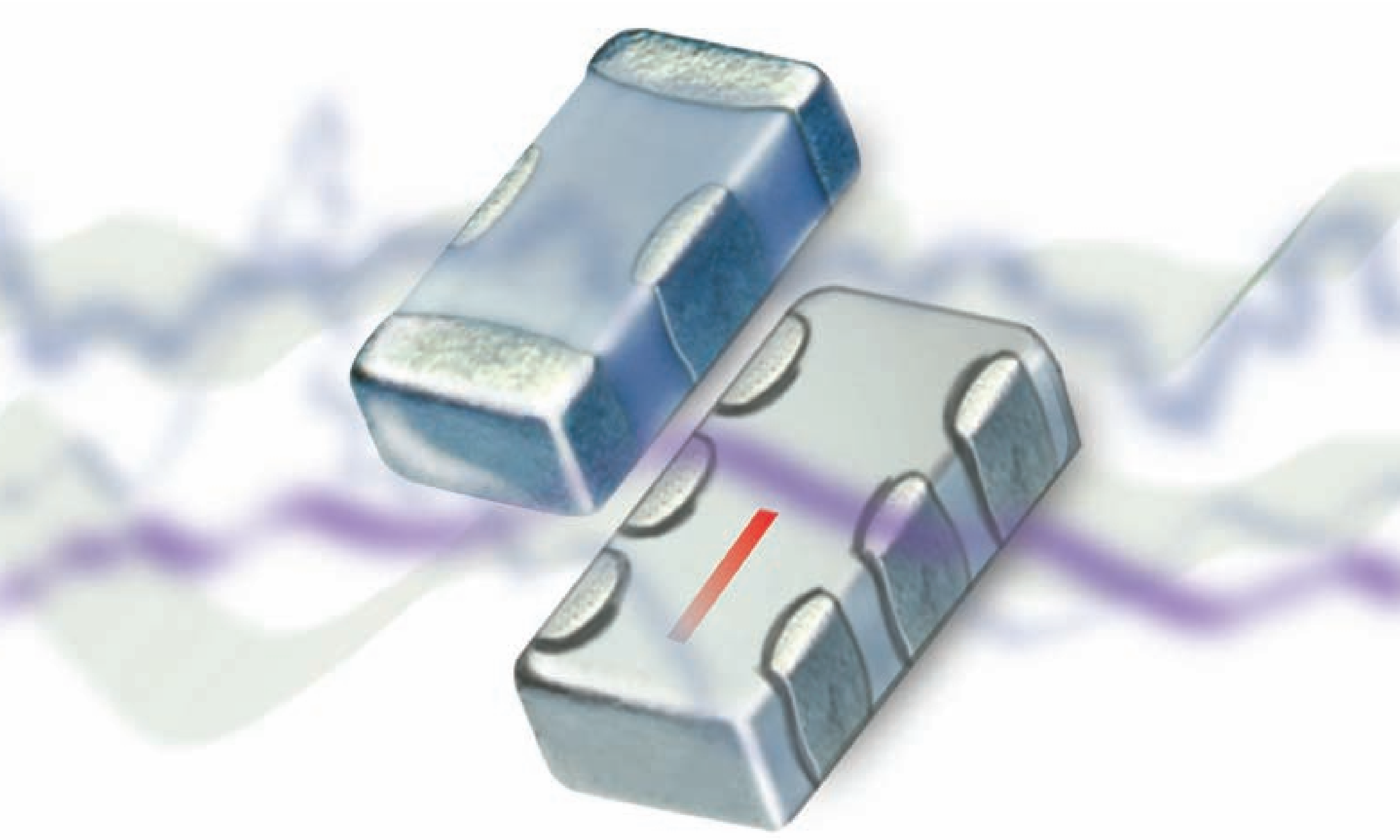
▲ *Ingo Bretthauer*

■ Twenty-five year microwave industry veteran **Nathan Lader** has been appointed as the new vice president of military, aerospace and government (MAG) programs for RF systems, a new division formed uniting the Nucomm and RF Central companies and sales teams. In his new position, Lader oversees and conducts the business development, sales and marketing efforts for the MAG division. Prior to his current role at RF Systems, Lader served as a marketing and contract administrator with Hughes Aircraft Co. where he managed budgets, projects and participated in technical and cost articles for government and military customers.



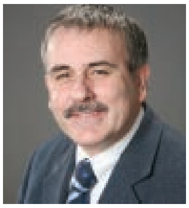
▲ *Nathan Lader*

■ Renaissance Electronics announced the promotion of **Michael Snee** to vice president of the switch product division. Snee has been with Renaissance for over 10 years in



sales and most recently as vice president of procurement, handling purchasing. Snee has been in the RF industry for over 25 years, and will now be responsible overall for the company's switch product division.

■ Endicott Interconnect Technologies Inc. (EI) announced that it has created EI Technologies UK Ltd., a wholly owned subsidiary of EI and located in Chelmsford, UK. **Steve Payne** has been named director of European sales. Payne will assume the role of managing the newly formed UK office, with EI's European manufacturing representatives reporting to him. By leveraging EI's innovative technology and production capabilities, Payne is also tasked with account penetration of segments targeted for future growth in the European marketplace.



▲ *Steve Payne*

■ **William Shifman** joins Reactel with over 10 years of Quality Management and Manufacturing Engineering experience. Shifman's skills in the areas of continual improvement and waste reduction will propel Reactel Inc. forward in its ability to meet and exceed the high quality expectations of the company's customers.

■ MI Technologies announced that it has realigned its European customer support and service function to provide enhanced service and faster, more direct communications. As part of the realignment, the company has expanded its customer support staff in its United Kingdom service center to support customers in the European region. In a related move, the company has discontinued the use of Cal Info Mesure to support European customers. As part of the program to expand European customer support services, the company announced the appointment of **Richard Whalley** to its customer support staff in the UK. Whalley joins MI Technologies with more than 24 years experience in microwave and RF test and measurement engineering support including extensive field experience.

REP APPOINTMENTS

■ **Mouser Electronics Inc.** announced it has signed a distribution agreement with **Wurth Electronics Midcom Inc.**, a company that focuses on the manufacture of inductors through its EMC and Inductive Solutions unit. Mouser stock includes inductors, EMC components, common mode chokes, snap-on ferrite line chokes, ferrite beads and modular filtered jacks.

■ **Digi-Key Corp.** and **Cree Inc.** announced that Digi-Key is now stocking Cree's Gallium Nitride (GaN) HEMT transistors for general purpose microwave applications. Digi-Key's portfolio of Cree offerings encompasses SiC power components, SiC MESFETs, high brightness and high power LEDs, and now, GaN HEMT transistors. Cree's GaN HEMT general-purpose transistors, in power levels ranging from 10 to 90 W, are ideal for microwave applications that require high efficiency, multi-octave bandwidth performance.

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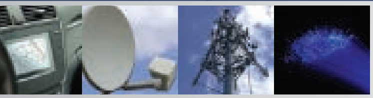

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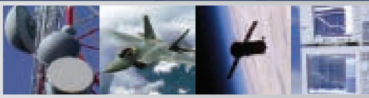

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- ♦ Efficient: Fast Frequency Switching, 200 µs
- ♦ Accurate: Incorporates Hittite MMICs
- ♦ Flexible: Manual or Software Control via USB

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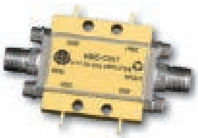
	Part Number	Function	Application
	Increase Ouput Power		
	HMC-C004	0.01 - 20 GHz Widbeband Driver Amplifier	Increase HMC-T2000 Pout to +23 dBm
NEW!	**HMC-C057**	0.1 - 20 GHz, Power Amplifier	Increase HMC-T2000 Pout to +28 dBm
	HMC-C013	1.8 - 2.2 GHz, Power Amplifier, 10 Watt	Increase HMC-T2000 Pout to +40 dBm for Cellular / 3G
	Extend Frequency Range		
	HMC-C005	0.5 - 18 GHz, Divide-by-2 Prescaler	Extend HMC-T2000 Lower Frequency Limit to 400 MHz
	HMC-C056	4 - 10.5 GHz, x2 Active Frequency Multiplier	Extend HMC-T2000 Upper Frequency Limit to 16 GHz
	HMC-C032	9 - 14.5 GHz, x2 Active Frequency Multiplier	Extend HMC-T2000 Upper Frequency Limit to 29 GHz [1]
	HMC-C033	12 - 16.5 GHz, x2 Active Frequency Multiplier	Extend HMC-T2000 Upper Frequency Limit to 32 GHz [1]
	HMC-C034	16 - 23 GHz, x2 Active Frequency Multiplier	Extend HMC-T2000 Upper Frequency Limit to 46 GHz [2]
	Extend Dynamic Range		
	HMC-C018	DC - 13 GHz, 6-Bit Digital Attenuator	Extend HMC-T2000 Dynamic Range by 31.5 dB
	HMC-C025	DC - 20 GHz, 6-Bit Digital Attenuator	Extend HMC-T2000 Dynamic Range by 31.5 dB
	HMC-C053	DC - 20 GHz, Voltage Variable Attenuator	Extend HMC-T2000 Dynamic Range by 31.5 dB
	Add Pulsed & Multi-Port Capability		
	HMC-C019	DC - 20 GHz, SPST Hi Isolation Switch	Add Pulsed Testing Capability, 8.5 ns Switching
	HMC-C011	DC - 20 GHz, SPDT Hi Isolation Switch	Add Multi-port Capability, 40 dB Isolation

[1] with the HMC-C056 [2] with the HMC-C056 & HMC-C032



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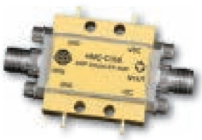

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RFID: THE NEXT GENERATION AUTO-ID TECHNOLOGY

Auto-ID technology is implemented in several different ways, including barcodes, lasers, voice recognition and biometrics. These techniques suffer from limitations such as the need for line-of-sight (LOS) with the interrogator (lasers and barcodes), low data storage capacities (barcodes) and the need for human intervention (voice recognition and biometrics).

Radio Frequency Identification (RFID) was developed to overcome these limitations. RFID provides an Auto-ID technology that does not require LOS, has a longer read range, can store large amounts of user data using integrated technology and allows changes to the stored data. RFID proves useful when traceability through process or life cycles is required; where data errors are high, such as in material identification or handling; and where business systems need more information than automatic identification technologies like bar coding can provide.

RFID is one of the most promising, rapidly developing, convenient, easy-to-use technologies, which uses radio frequency (RF) signals for automatic identification of objects/items. It offers the advantage of read/write (R/W) capability without being limited by line-of-sight type of propagation, can function under a variety of environmental conditions, provides a high level of data integrity and high level of security.[1-3] RFID enables machine-to-machine communication and event driven communication, where data is provided and processed in real time.[4] RFID, using the simplest form of electronics, is available in a choice of form and function that is virtually limitless.

HISTORY AND BENEFITS OF RFID

Although RFID found implementation in tracking supplies in the late 1980s, it has been in existence since 1939,[5,6] when it was first used as an Identify Friend or Foe (IFF) technique in World War II to identify whether airplanes were friend or foe, during night operations by the British Royal Air Force.

Another early work exploring RFID is the landmark 1948 paper by Harry Stockman,[7] who predicted that "...considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved and before

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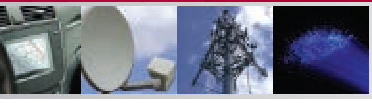

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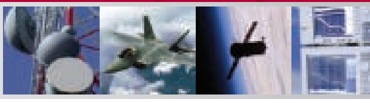

High Speed Comparators

- RSPECL, RSCML & RSECL Versions
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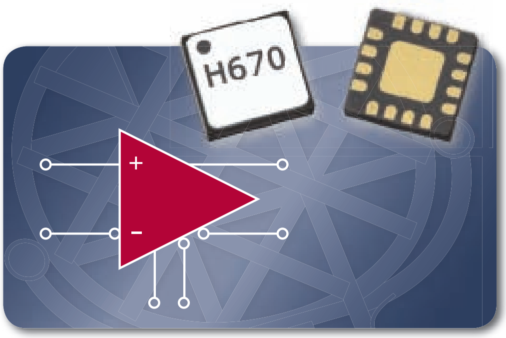

HIGH SPEED COMPARATORS

Input Clock Rate (GHz)	Function	Deterministic Jitter (ps)	Propagation Delay (ps)	Output Voltage Swing (Vdc)	DC Power Consumption (mW)	Vcc, Vee Power Supply (Vdc)	Package	Part Number
9.7	Latched Comparator-RSPECL	10	130	0.4	180	+3.3, -3.0	LC3C	**HMC674LC3C**
9.7	Latched Comparator-RSCML	10	130	0.2	120	+3.3, -3.0	LC3C	**HMC675LC3C**
9.7	Latched Comparator-RSECL	10	130	0.4	120	+3.3, -3.0	LC3C	**HMC676LC3C**

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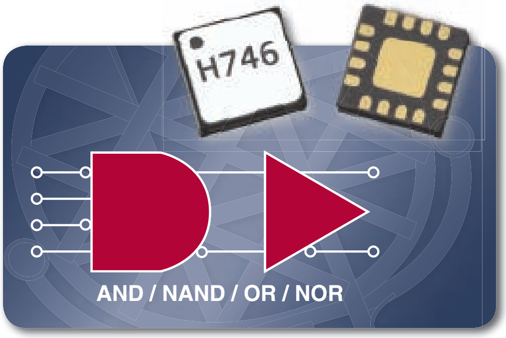

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	Data / Clock Rate (Gbps/GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vpp)	DC Power Consumption (mW)	Vee Power Supply (Vdc)	Package	Part Number
NEW!	13 / 13	Fast Rise Time 1:2 Fanout Buffer*	22 / 20	2	0.6 - 1.2	290	+3.3	LC3C	**HMC744LC3C**
NEW!	13 / 13	2:1 Selector*	22 / 22	2	0.6 - 1.2	250	+3.3	LC3C	**HMC748LC3C**
NEW!	13 / 13	Fast Rise Time AND/NAND/OR/NOR*	22 / 21	2	0.6 - 1.2	230	+3.3	LC3C	**HMC746LC3C**
NEW!	13 / 13	Fast Rise Time D-Type Flip-Flop*	22 / 20	2	0.7 - 1.2	264	+3.3	LC3C	**HMC747LC3C**
NEW!	26 / 26	T Flip-Flop w/ Reset *	18 / 17	2	0.6 - 1.2	270	+3.3	LC3C	**HMC749LC3C**
NEW!	13 / 13	Fast Rise Time XOR/XNOR*	21 / 19	2	0.6 - 1.2	240	+3.3	LC3C	**HMC745LC3C**

* These products feature programmable output voltage.

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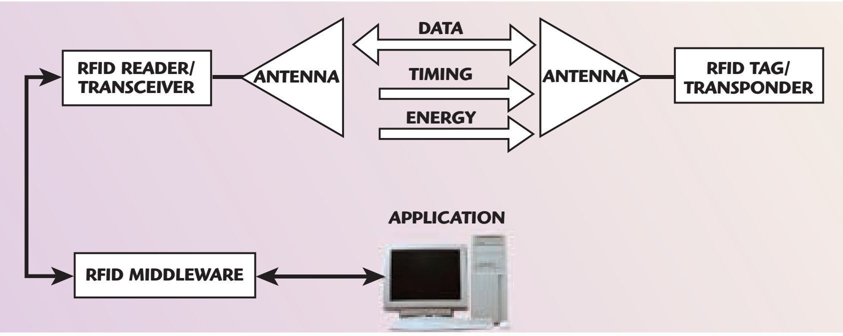

▲ *Fig. 1 Typical RFID system components.*

the field of useful applications is explored."

In the 1960s and 1970s, RFID tags found military applications such as equipment and personnel tracking[8,9] and some unique commercial applications such as identification and temperature sensing of cattle. The technology has now evolved for use in the railroad industry to track railroad cars, in the automotive industry for automation and tracking purposes, in agriculture and wildlife management to track livestock and wildlife, and in retail as an anti-theft device.

Mario Cardullo claims that his 1973 US Patent 3,713,148, a passive radio transponder with memory, was the first true ancestor of modern RFID. The first demonstration of today's reflected power (backscatter) RFID tags were done at the Los Alamos Scientific Laboratory in 1973.[6] However, the major development in RFID tracking came only in the 1980s and 1990s, when industrial goods needed counterfeit protection, shrinkage protection and tracking through the several stages in the supply chain. In the 1980s, Compaq computer started using RFID tags to trace components through the production process. RFID technology prevents theft or counterfeiting of goods, thus providing security, automatic counting of goods that enter or leave warehouses, thus allowing to keep track of the stock levels. Passive UHF RFID systems are increasingly being employed in distribution and supply chains.

The initial benefits of RFID in a warehouse or distribution center environment are mainly derived from automating manual processes and effectively using greater amounts of data. For example, using RFID tags to automate the receiving operation can reduce the labor cost for that function, as well as enhance accuracy and help decrease the amount of time that a carton spends in a distribution center. All the benefits of using an RFID system depend on the varying levels of RFID use, from pallet tagging to item tagging. At the pallet tagging level, RFID offers improvements in product diversion, production planning, inventory control and storage, and vendor-managed inventory programs, among other places. At the case tagging level, RFID presents opportunities for improved demand and supply planning, theft identification, and pick, pack and ship control. In item tagging, RFID allows a variety of benefits, including store-level promotions and pricing, item theft prevention, and capacity planning, among many others.[2]

RFID SYSTEM ARCHITECTURE

A typical RFID system is composed of the following four components, as shown in ***Figure 1***.

RFID Tags or Transponders

Historically, an RFID device that did not actively transmit to a reader was known as a tag. An RFID device that actively transmits to a reader was known as a transponder (TRANSmitter + resPONDER). However, it has become common within the industry to interchange the terminology and refer to these devices as either tags or transponders.[1,9]

A tag's performance parameters are its read range, transmission speed (data rate) and the impact caused by surrounding objects. The frequency, the orientation to the reader field, and the design and size of the anten-

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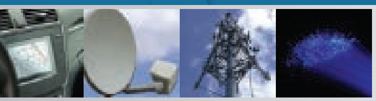

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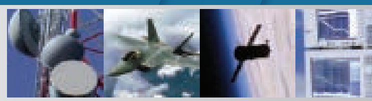

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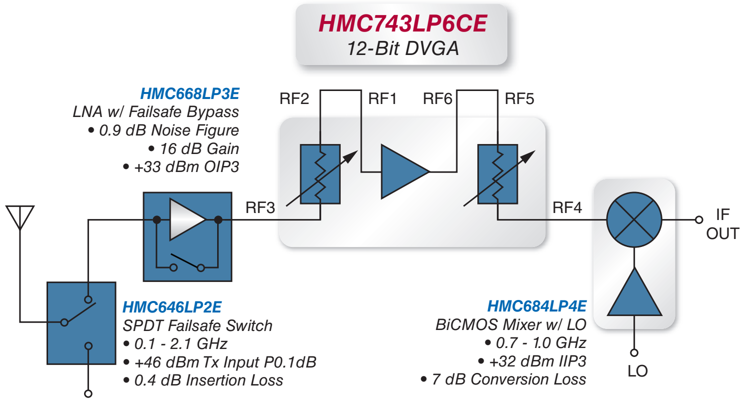

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IN-STOCK VARIABLE GAIN AMPLIFIERS - ANALOG & DIGITAL

	Frequency (GHz)	Function	Gain Control Range (dB)	NF * (dB)	OIP3 (dBm)	P1dB (dBm)	Bias Supply	Package	Part Number
	0.4 - 3.0	Analog VGA	-25 to +20	5	40	23	+5V @ 265mA	LP5	**HMC640LP5E**
	6 - 17	Analog VGA	+1 to +23	5	30	22	+5V @ 170mA	Chip	**HMC694**
	6 - 17	Analog VGA	+1 to +23	6	30	22	+5V @ 175mA	LP4	**HMC694LP4E**
NEW!	0.03 - 0.4	5-Bit Digital, Differential Outputs	-4 to +19	6.5	40	25	+5V @ 250mA	LP4	**HMC680LP4E**
	0.05 - 0.8	5-Bit Digital, Serial & Parallel Control	-8 to +15	5	35	18	+5V @ 65mA	LP4	**HMC628LP4E**
	DC - 1	6-Bit Digital, Serial & Parallel Control	-11.5 to +20	4.3	36	20	+5V @ 90mA	LP5	**HMC627LP5E**
	DC - 1	6-Bit Digital, Parallel Control	+8.5 to +40	4	36	20	+5V @ 176mA	LP5	**HMC626LP5E**
	DC - 1	6-Bit Digital, Serial Control	+13.5 to +45	2.7	36	20	+5V @ 176mA	LP5	**HMC681LP5E**
	DC - 6	6-Bit Digital, Serial & Parallel Control	-13.5 to +18	6	33	19	+5V @ 88mA	LP5	**HMC625LP5E**
NEW!	0.7 - 1.2	6-Bit Digital, Serial & Parallel Control	-3.5 to +28	0.8	38	21	+5V @ 236mA	LP5	**HMC707LP5E**
NEW!	1.7 - 2.2	6-Bit Digital, Serial & Parallel Control	-3.5 to +28	1.0	37	21	+5V @ 252mA	LP5	**HMC708LP5E**
NEW!	DC - 4	12-Bit Digital, Serial Control	-45 to +18	6	33	18	+5V @ 82mA	LP6C	**HMC743LP6CE**

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Receive the latest product releases at www.hittite.com - click on "My Subscription" na determine an RFID tag's read range and its flexibility to environment factors. The frequency and the associated transmission protocol (anti-collision algorithm) determine the basic rate of data transmission.[4]

RFID tags are further divided into active and passive tags. An RFID device that uses a battery and actively transmits to a reader is termed an "active" tag. An RFID tag that only reflects or backscatters transmission from a reader is termed "passive". In general, active tags use batteries to power the tag transmitter (radio) and receiver. Active tags are usually larger in size and more expensive than passive tags. The life of an active tag is directly related to battery life.

RFID Readers or Transceivers

The RFID reader or transceiver is the source of the RF energy used to activate and power the passive RFID tags. It transmits the RF signals, receives the encoded signal from the tag, decodes the tag's identification and transmits the identification data to the host computer.[1]

The reader antenna establishes a connection between the reader electronics and the electromagnetic wave in the space. In the UHF range, reader antennas (like tag antennas) come in a variety of designs. Highly directional, high-gain antennas are used for large read distances. Regulatory authorities usually limit the maximum power emitted in a given direction (transmission power plus the antenna gain). The antenna gain is linked to the antenna size; the higher the gain (or smaller the solid angle into which the antenna emits), the larger the mechanical design of the antenna will be. Highly directional antennas are not used for handheld readers. Antennas typically used for handheld readers include patch antennas, half-wave dipoles and helix antennas. Larger antenna structures can be used for stationary readers. In the UHF range, they usually take the form of arrays. The size determines the far field of such antennas.[4]

RFID Middleware

RFID middleware connects the RFID reader layer to the business applications. Its task is to process RFID events and present them to the business applications in such a way that they can be processed further by those applications. The middleware also monitors the RFID hardware (readers, antennas and so on). This involves sending confirmations to the feedback providers and monitoring the sensors (light barriers, timers, motion detectors), since this cannot be combined initially with the casual process logic.[4] The primary function of the RFID middleware is filtering, which is to read all the tags at a location ensuring that the same electronic product code (EPC) tags are not read over and over again.[10]

RFID Application Software

The RFID reader is connected to the host computer, which is used to program the reader and store information received from the transponder. As a result of a service-oriented architecture (SOA), software is configured and adapted for different applications. Software development tools can be used to organize the individual services in line with process requirements. Web services, Extensible Markup Language (XML), message queuing, and workflows are elements of an SOA and of RFID middleware that can be used to link different services.[4]

WORKING OF RFID SYSTEM

RFID is similar in concept to bar coding.[1] Bar code systems use a reader and coded labels that are attached to an item, whereas RFID uses a reader and special RFID devices that are attached to an item. Bar codes use optical signals to transfer information from the label to the reader; RFID uses RF signals to transfer information from the RFID device to the reader.

Radio waves transfer data between an item to which a RFID device is attached and an RFID reader. The device can contain data about the item, such as what the item is, what time the device travelled through a certain zone, perhaps even a parameter such as temperature. RFID devices, such as a tag or label, can be attached to virtually anything, from a vehicle, as shown in ***Figure 2***, to a pallet of merchandise. The reader and tag communicate using the antennas and

a defined command set. The communication protocol is defined such that the reader first sends a command and the tag responds. The command set includes commands to read and write data, to control the anti-collision protocol, to lock individual memory cells, and to deactivate the tag (kill command).

The classification of UHF RFID tags is also based on their operation and functionality,[11,12] as detailed below:

• Class 0 - passive read only tags

They use out of band signaling and backscatter technique to communicate to the reader.

• Class 1 - write-once-read-many (WORM) passive tags

The programming of the tags can be done by the manufacturer or by the user, but only once. The tags use in band signaling and backscattering.

• Class 2 - additional storage capacity and encrypted passive tags

They use backscattering to communicate with each other.

• Class 3 - semi passive tags

The tags have a battery source to operate the internal circuitry. However,

Fig. 2 An RFID tag used for electronic toll collection (source: www.wikipedia.com).

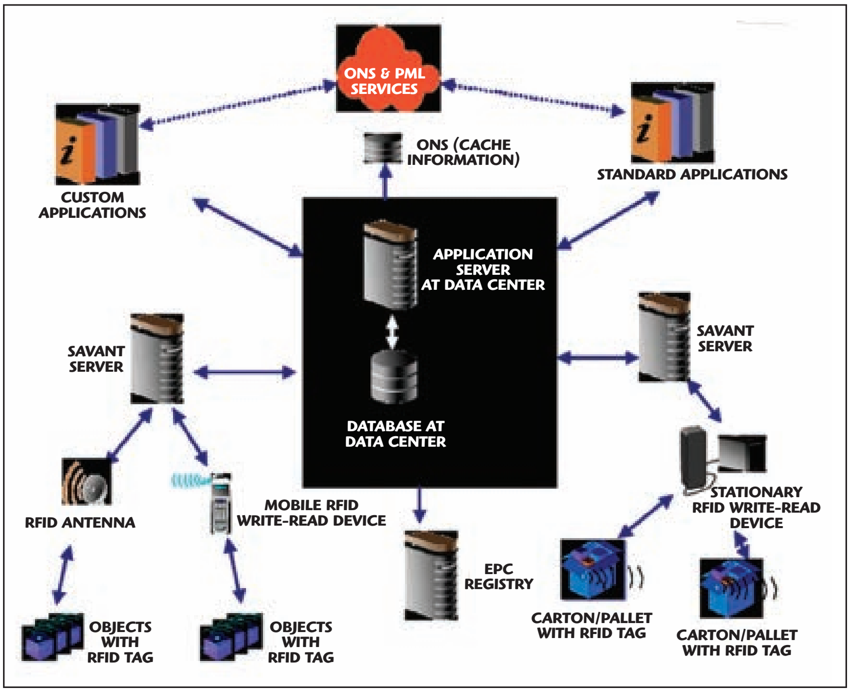

Fig. 3 EPC global oriented RFID applications and communication structure (source: Oracle/GSI Germany).

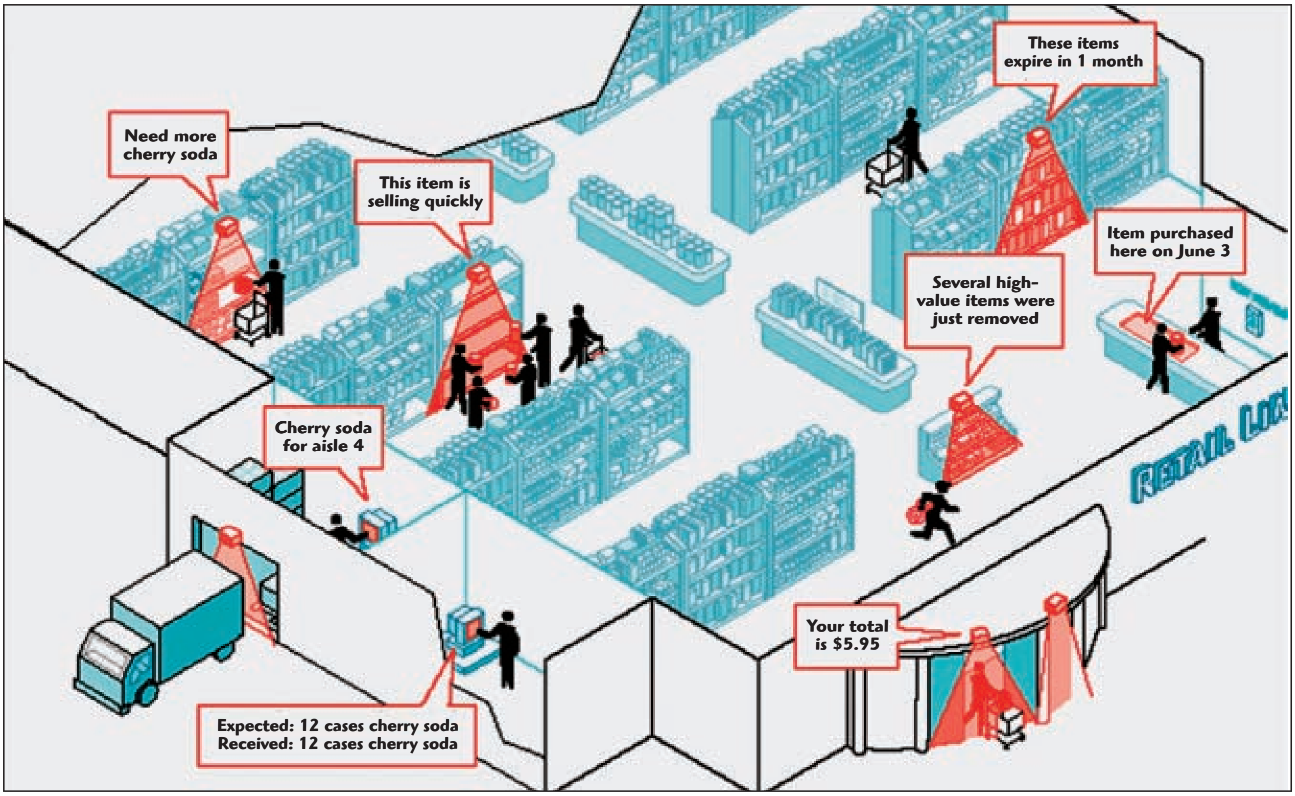

Fig. 4 Supply chain using an RFID system (source: www.ficci.com).

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they do not have a transmitter to send across signals to other tags/readers. They also use backscattering for reader communication.

• Class 4 - active tags
The tags have battery source to supply power to the internal circuitry and have a transmitter too. These tags are also capable of communicating with other tags that have the same technology.

• Class 5 - active tags with additional capability
The tags have the additional capability of successfully powering other ICs of peer class and lower classes and can have two-way communication with Class 4 tags. RFID readers come under this category.

Figure 3 illustrates how complex the flow of data can be through IT systems operating with RFID procedures. In this case, RFID data is fed via RFID middleware servers to a company's central data center. The data center runs the conventional business applications, whereby distinguishing between central and local data management is needed. With central data management, only an object's identification number is transferred (the information on the tag). Any other data associated with the object is stored in central databases.[4]

The Savant™ system is a hierarchical control and data management building block that can be used to provide automated control functionality and manage the large volumes of data generated by the RFID readers. A Savant enables the distributed creation of a reader network by acting as a gateway to the next higher level in

TABLE I
RFID FREQUENCY RANGES, STANDARDS AND THEIR KEY APPLICATIONS

RFID	KEY APPLICATIONS	STANDARD
125 kHz (LF)	Inexpensive passive RFID tags for identifying animals	ISO 18000-2
13.56 MHz (HF)	Inexpensive passive RFID tags for identifying objects, e.g., library books identification, clothes identification, etc.	ISO 14443
400 MHz	For remote control for vehicle centre locking systems	ISO 18000-7*
868 MHz, 915 MHz & 922 MHz (UHF)	For active and passive RFID tags for logistics in Europe, United States & Australia, respectively	Auto-ID Class 0 Auto-ID Class 1 ISO 18000-6
2.45 GHz (microwave)	An ISM band, used for active & passive RFID tags, e.g., with temperature sensors or GPS localization	ISO 18000-4
5.8 GHz (microwave)	Used for long read range passive and active RFID tags for vehicle identification, highway toll collection	ISO 18000-5

* *under development*

the Savant hierarchy, effectively isolating the reader sub-network. The use of Savants enables distributed security by providing convenient points for network isolation.

The Savant network further reduces the burden on the tags while providing several advantages. First, it reduces the memory and power requirements on the tags by transferring the computationally intensive functionality to a powered system. Second, it makes the system more robust; any single point of failure has local effects. Third, it enables the entire system to be scalable as systems and reader sub-networks may be added seamlessly. Finally, the Savant network significantly reduces the footprint of the tag's microchip, reducing the cost of the transponder.[3,13]

APPLICATIONS OF RFID

RFID is used in applications such as:[1,6]

- Asset identification and tracking
- Electronic toll collection
- Railway car identification and tracking
- Access control
- Item management for retail, health care and logistics application
- Animal identification
- Fuel dispensing loyalty programs
- Automobile immobilizing (security) - central locking systems

RFID functions are also integrated in passports of many countries, including Malaysia, Germany, the UK and the US, and is used in transportation systems for payments in many parts of the world—New York City subway, Moscow Metro, UK public transport, Taiwan transportation system, Hong Kong, Paris public transport system, Western Australia Transperth public transport network, etc. RFID tags will soon be on our health cards.

Figure 4 shows a nearly perfect supply chain visibility, which eliminates human error from data collection, reduces inventories, keeps product in-stock, reduces loss and waste, and improves safety and security.[14] Most RFID applications are currently found in "closed" processes, where the tags are reused time and again and within one organization or company. One example of 'closed loop' is in a library to register the books on loan and in areas requiring document management. The retail industry usually operates "open" systems with labels on the packaging that are discarded at the end, together with the RFID tags. Such cases are referred to as 'open loop'.[4]

RFID STANDARDS

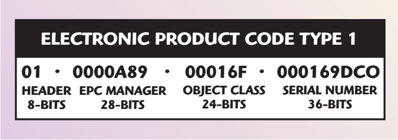
EPCglobal Inc., a division of GS1 (Global Standards 1 is an organization created by combining the former UCC and EAN organizations), has developed a new Electronic Product Code (EPC) as the next standard for tracking products through the supply chain. EPC utilizes the basic structures of the Global Trade Item Number (GTIN) and Serialized Shipping Container Code (SSCC), as well as others.[15] EPCglobal Inc. has also defined a global protocol operating in the UHF range for carton and pallet labeling. This protocol, referred to as EPC Class 1 Generation 2 (or "Gen 2"), will replace several older Class 1

protocols that did not provide global interoperability.

While EPCglobal focuses mainly on open-loop supply chain tracking application, ISO (The International Organization for Standardization) has many RFID protocols defined at various frequencies and for numerous applications, as shown in ***Table 1***. The 18000 standards describe measurement procedures for checking RFID structures.[3,4,16]

THE ELECTRONIC PRODUCT CODE (EPC)

The EPC is a 96-bit number made up of a header and three sets of data. There are several iterations of the EPC, depending upon the specific application. EPC is currently the most common encoding scheme for warehouse and distribution applications. EPC tags can be active or passive, read-only or read-writable. An example of a typical EPC code is shown in ***Figure 5***. The header identifies the EPC version number, which identifies the type of EPC data to follow. The second part of the number identifies the EPC manager; typically, it is the manufacturer of the item the EPC is attached to. The third part is called object class and refers to the exact type of product—stock-keeping unit (SKU). The fourth series of numbers is the serial number that is unique to the item.[15] A 96-bit EPC will allow sufficient capacity for 268 million companies. Each manufacturer will have the ability to create up to 16 million object classes with 68 billion serial numbers in each class.



▲ *Fig. 5 Typical EPC code (source: www.paxar.com).*

RFID INDUSTRY: LARGE AND UNKNOWN

Not all industries are expected to be equally likely to adopt RFID technologies. Some industries (like consumer electronics, pharmaceuticals and toys) are likely to rollout their implementations earlier due to suitable product attributes and category economics.

In June 2003, Wal-Mart greatly advanced the process of adoption when it announced that starting in January 2005, 100 of its top suppliers would need to tag all pallets and cases going to some Wal-Mart warehouses. Wal-Mart began its RFID pilot project on April 30, 2004. The eight suppliers that started shipping a handful of RFID-enabled pallets were Gillette, Hewlett-Packard, Johnson & Johnson, Kimberly-Clark, Kraft Foods, Nestle Purina Petcare, Procter & Gamble and Unilever. The Department of Defense (DoD), Target and Albertsons announced their future RFID-tagging requirements to their suppliers.[4,12,17,18]

Recently, several companies across the drug supply chain have been testing RFID deployment. European giants, such as Marks & Spencer and Tesco, have started piloting RFID tags in clothing, CDs and DVDs. In Australia, Coles Myer started a pilot in-house RFID trial in May 2004,

which involves moving cages from one distribution center onto a truck then onto a receiving dock that the equipment recognises.

Market analysts, like Frost and Sullivan and ARC Advisory Group, expect the use of passive UHF RFID in manufacturing supply chain applications to achieve phenomenal growth over the next five years. Researchers predict that worldwide revenues from RFID transponders will jump to \$2.8 B in 2009[19] and will be a \$20 B market by 2013.[12] According to Gartner, the use of RFID to capitalize on data flow in global supply chains could be one of the most significant developments since enterprises first explicitly recognized the importance of information flow in the supply chain.

RFID SECURITY ASPECTS

In terms of security, RFID tags are inherently less secure, mainly because of the lack of processing capacity on these devices to handle much more than their core functions. RFID data must be used in compliance with clear regulations concerning IT security as well as consumer and data protection. An RFID system is usually limited to the RFID tags, the reader and the data transferred in this space (air interface). It might also include the threshold between the reader and the middleware that processes the data recorded. This means that when implementing an RFID system and designing its security concept, one has to ensure that the middleware and back-end systems are suitably safeguarded.[20]

The basic rule of thumb, however, is that simple RFID systems should store and transmit minimal amounts of data and that the application only gets its 'intelligence' from the RFID data in the back-end systems. As long as only manufacturer and serial numbers are transferred and cannot be turned into usable information without a combination of detailed information from the back-end systems, the security risk posed by the use of RFID can be deemed negligible.[4]

CHALLENGES FOR RFID SYSTEM: PHYSICAL LIMITATION, TECHNICAL GLITCH, COST, STANDARDS AND CONSUMER CONCERNS

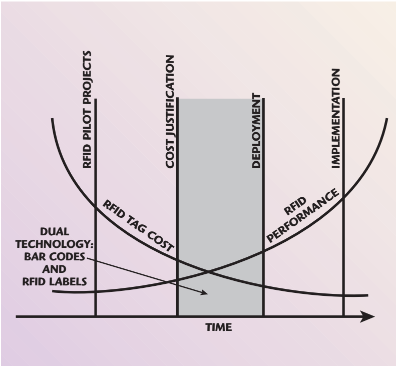
The readability of the tags is heavily dependent on the materials, the structure and the places where the tags are located. For instance, it is very difficult to read a UHF tag if it is surrounded by metallic objects, liquids, or other highly conductive or reflective materials. Sometime a tag must be affixed to the outside of a batch (on a pallet, for example). It may be covered at most by paper, expanded polystyrene, or similar materials.[4]

So far, one technical hitch[2] in introducing global RFID standards into Australia has been the level of power that reading devices can transmit on the designated 900 MHz bandwidth, as Australian devices have been re-

stricted to using only one watt of power with a range of three to four meters. The standard in the US is four watts.

RFID is still more expensive than barcode technology. ***Figure 6*** shows the RFID Timeline, as the RFID performance curve climbs to the right, there is a point at which the performance, or benefit, provided by using RFID tags begins to exceed the cost of the tags. It is at this point that adoption of RFID potentially begins to make business sense. As RFID is widely adopted, the cost of tags will fall in typical supply-demand fashion and RFID implementation that is too expensive today may become affordable in a matter of time.[2]

RFID standards are evolving and are still in an infant stage. Consumers are concerned about the abuse of the system and that this will have a negative effect on them, especially in regards to their privacy. Also, consumers are concerned about the health effects of the network's radio waves.[12,17] While these and other challenges would be tackled as the technology advances and moves closer to the mainstream, in the interim they will slow down the adoption process.



▲ *Fig. 6 RFID timeline (source: FXI Logistex, 2006).*

CONCLUSION

RFID is expected to provide huge advantages to manufacturers by offering the tools to better plan production and respond more quickly to market demand. It will facilitate automation of inventory counts and speed shipping and receiving at the distribution level.[15] For retailers, it will help reduce stock-outs, enable product tracking and potentially reduce theft and streamline the point of sale (POS) function.

The Massachusetts Institute of Technology has coined the phrase 'The Internet of Things' to describe the vision of a future where Thing-to-Thing (T2T) communication takes place. Cradle-to-grave tracking of items without human intervention—the domestic freezer re-ordering supplies directly from the supermarket and the food telling the microwave how to cook it—are the kinds of uses that are already being considered for commercial applications. Just how far RFID goes is a question of tagging economics and time.[22]

While RFID technology offers a variety of potential benefits and advantages over current barcode technology and would eventually replace it, the technical, financial and psychological challenges have prevented it from attaining wide use in warehouse and distribution center operations. In the near future, while RFID technol-

Product Brochure

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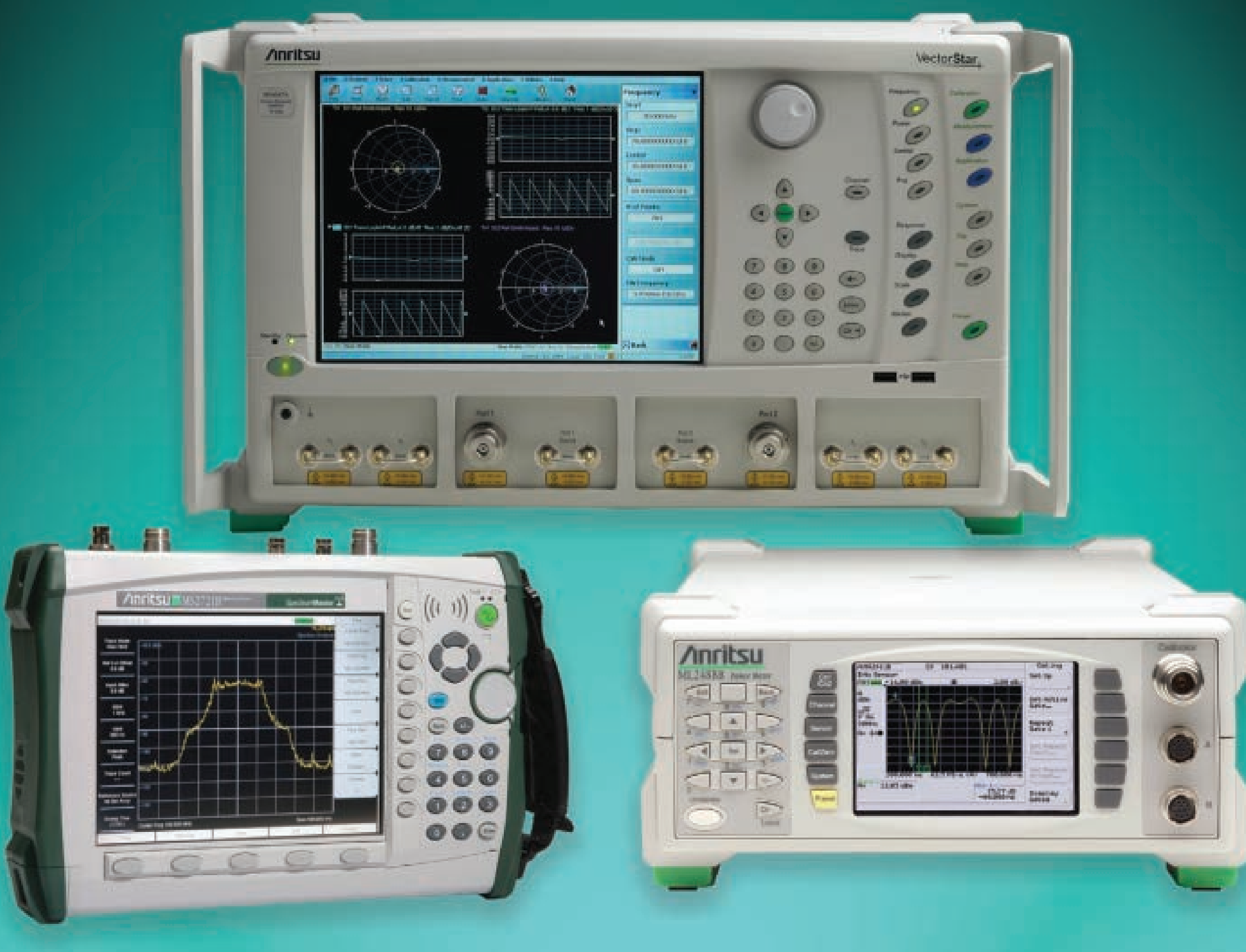
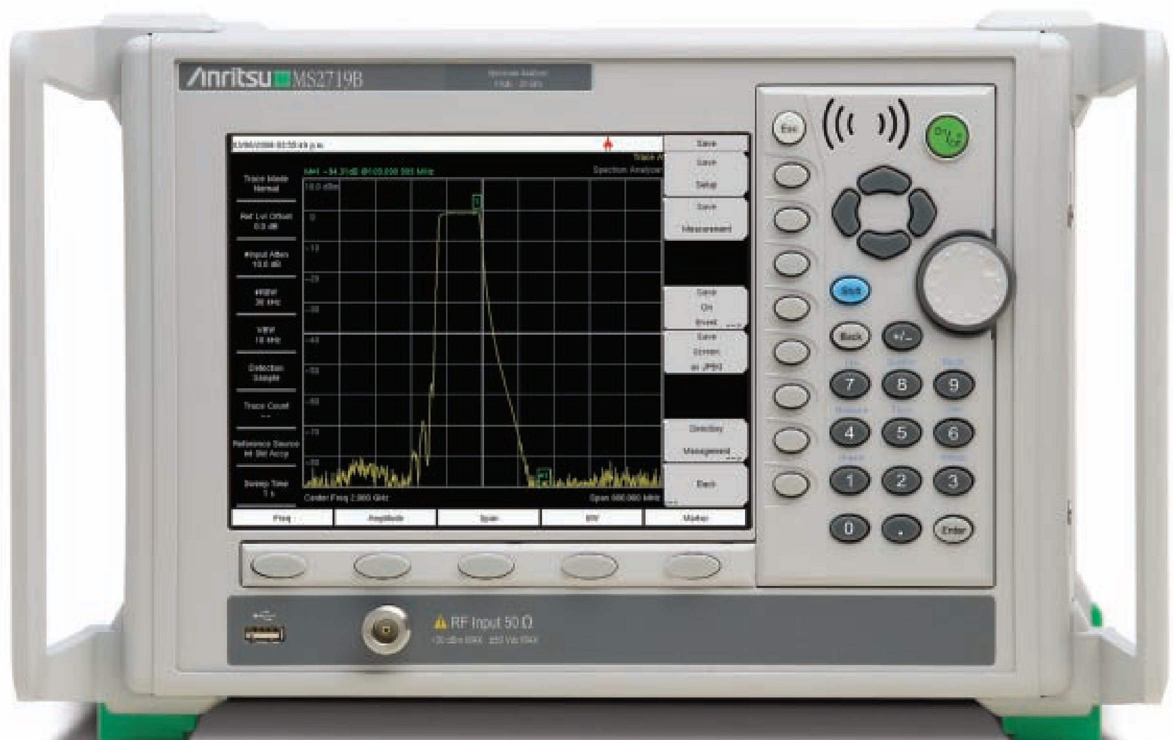


Spectrum Analyzers

Model	Frequency	RBW	Noise Level	Key Features
MS2661C	9 kHz to 3 GHz	30 Hz to 3 MHz	–130 dBm (option and frequency dependent)	■ Frequency counter ■ C/N ■ Adjacent channel power ■ Occupied-frequency bandwidth ■ Burst average power ■ Noise power ■ PASS/FAIL limit lines
MS2663C	9 kHz to 8.1 GHz	30 Hz to 3 MHz	–130 dBm (option and frequency dependent)	
MS2665C	9 kHz to 21.2 GHz	30 Hz to 3 MHz	–130 dBm (option and frequency dependent)	■ Compact, lightweight (13 kg standard) ■ High C/N and superior distortion characteristics ■ Easy-to-use operation ■ Options support wide range of applications ■ MS2665C supports easy set up auto measurements ■ MS2667/68C supports millimeter applications
MS2667C	9 kHz to 30 GHz	10 Hz to 3 MHz	–135 dBm (option and frequency dependent)	
MS2668C	9 kHz to 40 GHz	10 Hz to 3 MHz	–135 dBm (option and frequency dependent)	
MS2681A	9 kHz to 3 GHz	1 Hz to 20 MHz	Down to –148.3 dBm (option and frequency dependent)	■ Fast data transmission speed (GPIB transmission speed:120 kbytes/second) ■ Optional measurement software for high-speed modulation analysis (1.5 seconds with W-CDMA, 0.5 seconds with IEEE 802.11a) ■ Optional narrow resolution bandwidth from 1 Hz
MS2683A	9 kHz to 7.8 GHz	1 Hz to 20 MHz	Down to –146.5 dBm (option and frequency dependent)	
MS2687B	9 kHz to 30 GHz	1 Hz to 20 MHz	Down to –146.5 dBm (option and frequency dependent)	■ Optional measurement software for high-speed modulation analysis (0.5 seconds with IEEE 802.11a) ■ Optional power meter that measures up to 32 GHz ■ Fast data transmission speed (GPIB transmission speed:120 kbytes/second)
MS2711D	100 kHz to 3 GHz	100 Hz to 1 MHz	–135 dBm	■ Typical dynamic range of 100 dB ■ Typical phase noise of –110 dBc/Hz at 10 kHz offsets up to 6 GHz ■ RF and demodulator measurement capabilities with pass/fail functions ■ 13 software options for wireless measurements from GSM to Mobile WiMAX
MS2717B MS2718B MS2719B	9 kHz to 7.1 GHz 9 kHz to 13 GHz 9 kHz to 20 GHz	1 Hz to 3 MHz	–153 dBm typical to 1 GHz	
MS2721B	9 kHz to 7.1 GHz		–163 dBm typical to 1 GHz, 1 Hz RBW	
MS2723B	9 kHz to 13 GHz		–156 dBm typical to 1 GHz, 1 Hz RBW –139 dBm typical to 1 GHz, 1 Hz RBW	
MS2724B	9 kHz to 20 GHz		–156 dBm typical to 1 GHz, 1 Hz RBW –136 dBm typical to 1 GHz, 1 Hz RBW	
MS2690A MS2691A MS2692A Signal Analyzer	50 Hz to 6.0 GHz 50 Hz to 13.5 GHz 50 Hz to 26.5 GHz	Spectrum Analyzer Mode 30 Hz to 20 MHz Signal Analyzer Mode 1 Hz to 1 MHz	Down to –155 dBm (option and frequency dependent)	■ World class dynamic range ■ 125 MHz analysis bandwidth ■ Excellent accuracy of level and modulation analysis up 6 GHz ■ Excellent accuracy of level and modulation analysis up 6 GHz ■ High speed modulation analysis ■ Supports GSM/EDGE/EDGE evolution, HSPA, LTE, and Mobile WiMAX
MS8608A Digital Mobile Radio Transmitter Tester	9 kHz to 7.8 GHz	1 Hz to 20 MHz	Down to –146.5 dBm (option and frequency dependent)	■ Excellent performance for evaluating W-CDMA modulation signals ■ Supports GSM/EDGE, HSDPA, WLAN/802.11, CDMA, 1xEVDO, and Pi/4DQPSK (PHS, PDC, IS–136) measurements ■ Resolution bandwidth of up to 20 MHz via built-in spectrum analyzer ■ Power can be measured with an accuracy of ±0.4 dB using the power sensor
MS8609A Digital Mobile Radio Transmitter Tester	9 kHz to 13.2 GHz			

Take a closer look at Anritsu Spectrum Analyzers at www.anritsu.us/824

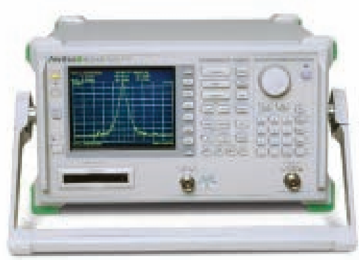
Take advantage of a **large selection of options** to handle a wider range of applications at a reasonable cost.



MS2719B

Spectrum Analyzers

Superior performance. Advanced capabilities. Affordable pricing. The Anritsu family of spectrum analyzers delivers high frequency/ level accuracies and a broad set of smart, intuitive features— including models with built-in one-button measurements.



MS2661C

MS2668C

Vector Network Analyzers

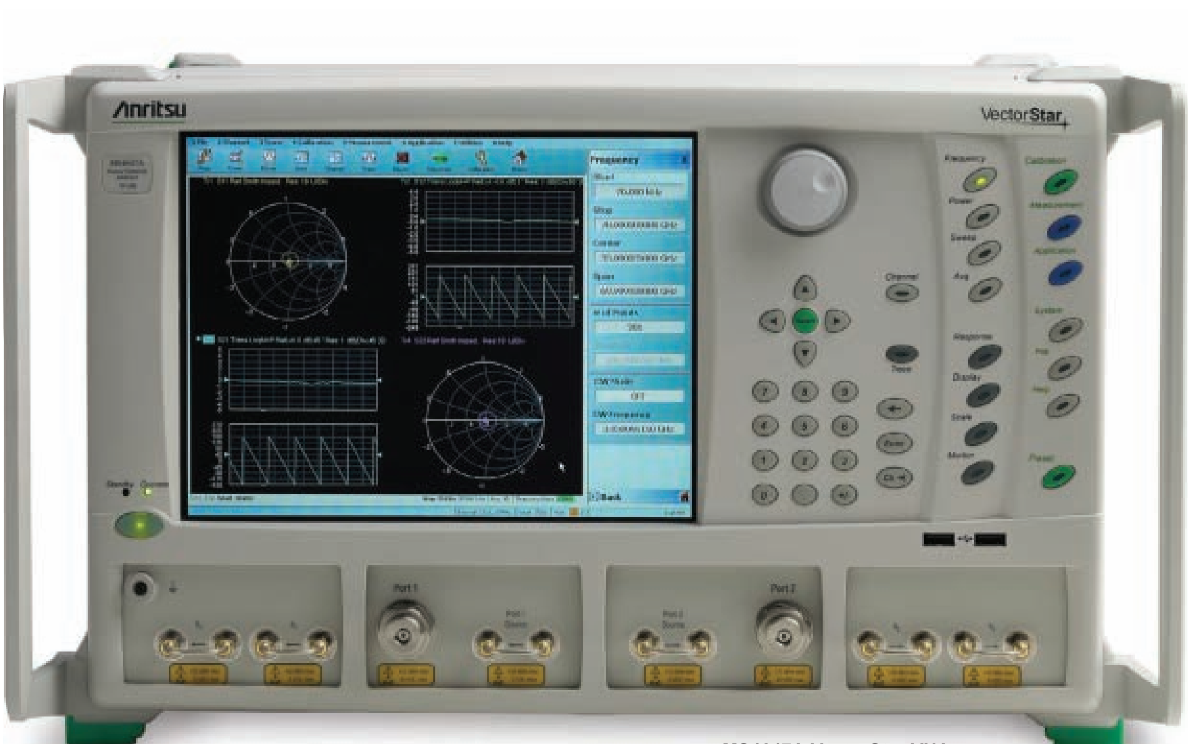
<table>
<tr><th>Vector Network Analyzer</th><th>Features</th><th>Benefits</th><th>Applications</th></tr>
<tr><td rowspan="9">VectorStar Family Microwave and mmWave VNA

MS4640A Series
70 kHz to 70 GHz

MS4642A Series
70 kHz to 10 MHz to 20 GHz

MS4644A Series
70 kHz to 10 MHz to 40 GHz

MS4647A Series
70 kHz to 10 MHz to 70 GHz</td><td>Broadest frequency span from a single coaxial test port covering 70 kHz to 70 GHz in a single instrument and 70 kHz to 110 GHz in the Broadband configuration</td><td>■ Obtain the most thorough and accurate broadband device characterization.
■ Eliminate time consuming concatenation process across the RF, microwave/ mm-wave bands.
■ Decrease test instrument expenses by eliminating the need for a 2nd RF VNA.
■ Reduce the risk of DC extrapolation errors in your device modeling.</td><td rowspan="9">■ Device characterization
■ Microwave and millimeter wave component test
■ On-wafer
■ Waveguide S-parameters
■ R&D and production environments
■ Mixer measurements including automatic de-embedded measurements with absolute phase and group delay
■ Embed/De-embed applications
■ Amplifier testing
■ Broadband characterization
■ Parameter extraction
■ Device modeling</td></tr>
<tr><td>Fastest swept synthesized measurement speed
< 20 µsec per point</td><td>■ Increase manufacturing revenue by increasing throughput.
■ Quickly and easily spot the most hard to find failures and reduce the risk of shipping defective products.</td></tr>
<tr><td>Superior Dynamic Range –
up to 140 dB</td><td>■ Accurately measure medium and high loss devices.
■ Catch all potential filter feed-throughs in out-of-band regions.</td></tr>
<tr><td>High compression point –
up to15 dBm at 70 GHz</td><td>■ Eliminate the need for additional attenuators.
■ Improve calibration and measurement accuracy.</td></tr>
<tr><td>Best test port characteristic – up to 50 dB Directivity, Source Match, Load Match</td><td>■ Reduce measurement uncertainty
■ Reduce measurement guard bands
■ Improve productivity
■ Optimum precision in R&D</td></tr>
<tr><td>Highest point resolution –
100,000 points</td><td>■ Zoom in on narrow band responses without re-calibration.</td></tr>
<tr><td>Best device modeling data</td><td>■ Accelerate design cycle
■ Accurate DC modeling
■ Eliminate the need for 2nd VNA</td></tr>
<tr><td>Best time domain analysis</td><td>■ 100,000 points and 700 kHz frequency step size provide the most accurate, highest resolved, Low Pass Mode measurements.
■ Measure long transmission lines with the best non-aliasing range.</td></tr>
<tr><td>Most convenient automatic calibration system with best accuracy</td><td>■ Use Precision AutoCal for an easy, one-button method of VNA calibration and better accuracy than traditional SOLT calibration.
■ Spend less time setting up the VNA for the next production run.</td></tr>
<tr><td>Lightning Family Microwave and mmwave VNA
40 MHz to 20, 40, 67 GHz</td><td colspan="2">■ Best performance to price ratio
■ Excellent dynamic range and test port characteristics provide accurate, reliable measurements.
■ Many of the advanced high performance features found in VectorStar including; wide range of calibration choices, AutoCal, Embedding/ De-embedding, multiple source control, and power meter correction.</td><td>■ Passive devices
■ Active devices
■ Mixers
■ E/O and O/E
■ On-wafer</td></tr>
<tr><td>MS4630B RF VNA
10 Hz to 300 MHz</td><td colspan="2">■ Accurate magnitude and phase measurements
■ Filter and resonator analysis functions
■ High-speed device evaluation</td><td>■ Passive filters, resonators for both R&D and manufacturing
■ Optimized for IF measurements</td></tr>
</table>



MS4647A VectorStar VNA

The **versatility to completely characterize** wireless components and systems.

Vector Network Analyzers

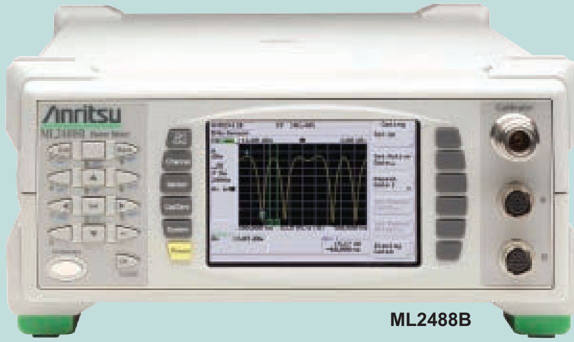
Anritsu VNAs encompass a wide range of high-performance, component test tools designed to address the growing needs of wireless, satellite, defense, broad-band communication and optoelectronic components markets. Choose between the VectorStar and Lightning family of VNAs for the ideal solution of advanced performance, accuracy and reliability for measuring any active or passive device or system – from characterization and designing to manufacturing and verification.

37397D

Power Meters | Signal Analyzers

Power Meters (RF Microwave)

Anritsu power meters provide accurate measurements for the full range of communications, wireless and aerospace applications.



ML2488B

Power Meter	Frequency	VBW	Dynamic Range (dBm)	Channels
ML2437A Power Meter	100 kHz to 65 GHz Sensor dependent	100 kHz	–70 to +20 dBm Sensor dependent	1
ML2438A Power Meter		100 kHz		2
ML2487B Wideband Peak Power Meter	50 MHz to 18 GHz Sensor dependent	20 MHz	–60 to +20 dBm Sensor dependent	2
ML2488B Wideband Peak Power Meter		20 MHz		2
ML2495A Wideband Peak Power Meter	100 kHz to 65 GHz Sensor dependent	65 MHz	–70 to +20 dBm Sensor dependent	1
ML2496A Wideband Peak Power Meter		65 MHz		2
ML2530A Calibration Receiver	100 kHz to 3 GHz	100 kHz	Range dependent	1

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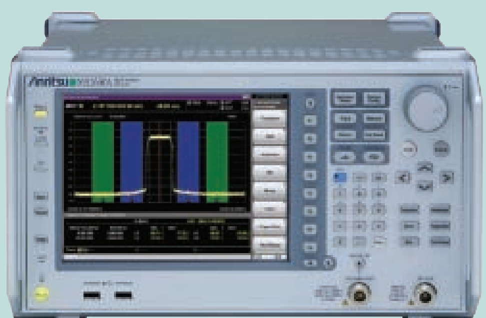

MS2690A

Signal Analyzer	Frequency	RBW	Noise Level	Key Features
MS2690A MS2691A MS2692A Signal Analyzer	50 Hz to 6.0 GHz 50 Hz to 13.5 GHz 50 Hz to 26.5 GHz	Signal Analyzer Mode 1 Hz to 1 MHz Spectrum Analyzer Mode 30 Hz to 20 MHz	Down to –155 dBm (option and frequency dependent)	■ World class dynamic range ■ 125 MHz analysis bandwidth ■ Excellent accuracy of level and modulation analysis up 6 GHz ■ Excellent accuracy of level and modulation analysis up 6 GHz ■ High speed modulation analysis ■ Supports GSM/EDGE/EDGE evolution, HSPA, LTE, and Mobile WiMAX

Anritsu provides the best synthesized signal generator solutions.

MG37020A

Synthesized Signal Generators

Whether you test in the microwave, fixed or mobile satellite communications or defense industries, Anritsu provides the best synthesized signal generator solutions. With high-signal purity, low noise and excellent frequency stability, our signal generators are a fundamental measuring instrument for your lab or manufacturing site. Choose instruments with a full range of modulation capabilities for signal simulations from simple to the most complex, including Amplitude (AM), Frequency (FM), Phase (ϕ) and Pulse (PM). Plus, you'll find a series of configurable and upgradable broadband high-performance signal generators that meet your exact specifications.

Signal Generator	Frequency Range	Key Features	Key Applications
MG3641A Synthesized Signal Generator	125 kHz to 1040 MHz	■ 0.01 Hz resolution ■ –100 dBc non-harmonic spurious	■ Radio receiver interference testing ■ On-site maintenance ■ R&D
MG3642A Synthesized Signal Generator	125 kHz to 2080 MHz	■ 0.01 Hz resolution ■ –100 dBc non-harmonic spurious	■ Radio receiver interference testing ■ On-site maintenance ■ R&D
MG3681A Digital Modulation Signal Generator	250 kHz to 3000 MHz	■ Broadband vector modulation ■ Excellent ACPR ■ Analog modulation	■ 3GPP applications ■ All major mobile and communication applications ■ HSDPA
MG3690B Series RF/Microwave Signal Generator	0.1 Hz to 67 GHz/325 GHz and greater	■ High-performance ■ High-output power ■ Ultra-low phase noise ■ Analog/Pulse modulation	■ Microwave communications ■ Aerospace/defense ■ Applications signal simulation ■ Manufacturing ATE systems
MG37020A Fast Switching Microwave Signal Generator	10 MHz to 20 GHz	■ Fast Switching Speed ■ High-output power ■ Low phase noise ■ Pulse modulation	■ Microwave communications ■ Aerospace/defense ■ Applications signal simulation ■ Manufacturing ATE systems
MG3700A Vector Signal Generator	250 kHz to 3 GHz (6 GHz option)	■ 160 MHz arbitrary waveform generator yields high-level accuracy and large capacity baseband memory	■ Digital modulation of signals for all major wireless communication systems
MG724E1/G1 Signal Generator	6.3 to 7.8 GHz 12 to 13 GHz	■ Compact high-performance	■ Line repeater ■ Maintenance

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S332D

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Site Master	Frequency	Measurements	
S311D Cable and Antenna Analyzer	2 MHz to 1600 MHz	■ Return Loss ■ Cable Loss	■ SWR ■ Distance-To-Fault
S331D Cable and Antenna Analyzer	2 MHz to 6000 MHz		
S312D Cable, Antenna and Spectrum Analyzer	2 MHz to 1600 MHz cable and antenna analyzer, 100 kHz to 1.6 GHz spectrum analyzer	■ Return Loss ■ SWR ■ Cable Loss ■ Distance-To-Fault ■ Adjacent Channel Power Ratio ■ P25 Transmitter and Coverage Measurements (S412D only)	■ Channel Power ■ Field strength ■ Interference Analysis ■ Occupied Bandwidth ■ Transmission Measurement
S412D Cable, Antenna, Spectrum, Interference, and P25 / iDEN Modulation Analyzer	2 MHz to 1600 MHz cable and antenna analyzer, 100 kHz to 1.6 GHz spectrum analyzer		
S332D Cable and Antenna Analyzer	2 MHz to 6000 MHz cable and antenna analyzer, 100 kHz to 3 GHz spectrum analyzer		
S810D Broadband Microwave Transmission Line and Antenna Analyzer	2 MHz to 10.5 GHz	■ Return Loss ■ 1-port Cable Loss	■ Distance-To-Fault ■ 2-port Cable Loss ■ Coax and waveguide VSWR
S820D Broadband Microwave Transmission Line and Antenna Analyzer	2 MHz to 20 GHz		

MT8222A

MT8212B

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Cell Master eliminates the need to carry, manage and learn multiple test sets. It includes a transmitter analyzer (GSM, CDMA, cdmaOne, CDMA2000 1xRTT, and CDMA2000 1xEV-DO), a transmission analyzer for 2-port devices, interference analyzer, channel scanner, GPS receiver, CW signal generator (tests LNAs, repeaters or base station receiver sensitivity) and T1/E1 analyzer.

Base Station Analyzer	Frequency	Measurements	
MT8222A BTS Master	10 MHz to 6 GHz (Built-in cable and antenna analyzer) 100 kHz to 7.1 GHz (Built-in spectrum analyzer) 10 MHz to 7.1 GHz (Built-in power meter)	■ Spectrum analysis ■ Interference analysis ■ Cable Loss ■ Mobile WiMAX (802.16-2005) ■ Fixed WiMAX (802.16–2004) ■ W-CDMA/HSDPA code domain power	■ Channel scanner ■ Return Loss ■ GSM/EDGE channel power ■ Distance-To-Fault ■ GPS receiver ■ CDMA/EVDO measurements
MT8212B Cell Master	25 MHz to 4 GHz (Built-in cable and antenna analyzer) 100 kHz to 3 GHz (Built-in spectrum analyzer) 4.5 MHz to 3.0 GHz (Built-in power meter)	■ Return Loss ■ Distance-To-Fault ■ Interference analyzer ■ Transmitter measurements (cdmaOne, CDMA2000 1xRTT, CDMA2000 1xEV-DO, GSM, iDEN)	■ Cable Loss ■ Channel scanner ■ GPS receiver ■ T1/E1 analyzer ■ Transmission analyzer for 2-port devices

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Handheld Analyzer for Next Generation Networks: Bit Master™

The Bit Master conducts economical mask compliance testing on transmitter outputs using eye pattern measurements. Fully portable, it serves engineers in the lab, production line, and in test labs.

MP1026B

Eye Pattern Analyzer	Frequency	Measurements
MP1026B Bit Master	0.1 to 12.5 Gbps	■ Supports OC-192/STM-64 SONET/SDH, 10G Fibre Channel, and 10G Ethernet ■ Optional integrated Optical/Electronic converter ■ Compliance masks and mask margin percentage for Industry Standards

Handheld Solutions

MS2026A

Handheld Vector Network Analyzers: VNA Master™

Need unparalleled performance and essential RF capabilities at modest prices? Enter the VNA Master series—simply the most advanced ultra-portable handheld VNAs on the market.

VNA Master	VNA Frequency	SPA Frequency	Measurements
MS2024A	2 MHz to 4 GHz	—	■ Return Loss ■ VSWR ■ 2-port phase ■ 2-port gain ■ Cable Loss ■ 1-port phase ■ Smith chart ■ Distance-To-Fault
MS2026A	2 MHz to 6 GHz	—	
MS2034A	2 MHz to 4 GHz	100 kHz to 9 GHz	MS202xA measurements plus: ■ High-performance spectrum analysis ■ Channel scanner ■ Interference analysis
MS2036A	2 MHz to 6 GHz	100 kHz to 9 GHz	

MS2721B

Handheld Spectrum Analyzers: Spectrum Master™

As the de facto industry standard, the Spectrum Master series provides ultimate measurement flexibility in a lightweight, rugged package for field environments and mobile applications. With frequencies ranging from 9 kHz to 20 GHz, the Spectrum Master is ideal for such applications as identifying sources of interference, measuring field strength of cellular, satellite and military land mobile signals, field analysis of 802.11a/b/g wireless LAN signals and measurement of RF output from circuits, devices and instruments.

Spectrum Master	Frequency	RBW	Noise Level (dBm)
MS2711D	100 kHz to 3 GHz	100 Hz to 1 MHz	–135 dBm
MS2721B	9 kHz to 7.1 GHz	1 Hz to 3 MHz	–163 dBm typical to 1 GHz in 1 Hz RBW
MS2723B	9 kHz to 13 GHz	1 Hz to 3 MHz	–156 dBm to 1 GHz, 1 Hz RBW –139 dBm to 3 GHz, 1 Hz RBW
MS2724B	9 kHz to 20 GHz	1 Hz to 3 MHz	–156 dBm to 1 GHz, 1 Hz RBW –136 dBm to 18 GHz, 1 Hz RBW

Specialized Products

Frequency Counters

Anritsu's frequency counters provide the most comprehensive frequency measurements in the industry.

Frequency Counter	Frequency	Key Features	Key Applications
MF2400 Microwave Frequency Counter	10 Hz to 20/27/40 GHz	■ Wideband measurement ■ High-accuracy burst measurement ■ Analog display function ■ Template function ■ High-speed transient measurement ■ Gating function	■ Mobile radio communications devices and circuits ■ Carrier frequency and pulse width of burst signal

Instrumentation Grade Attenuators

Highly accurate, versatile and economical, Anritsu Instrumentation Grade Attenuators also provide GPIB standard and feature automatic measuring system components.

Grade Attenuators	Frequency	Key Features	Key Applications
MN63A/65A/72A/64B Programmable Attenuator	DC to 18 GHz	■ Wide frequency range ■ High accuracy ■ Long operating life ■ High-speed switching	■ R&D ■ Inspection ■ Production

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Technicians rely on Anritsu for industry-leading design and production of precision microwave components.

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ogy strives to overcome these limitations and gain wider implementation, hybrid barcode-RFID systems will be the norm. However, taking into account the challenges and hurdles of exiting RFID technology, success will be more likely with short, well-defined and targeted projects. The 5 cents tag, as it has been called, has been widely viewed as the inflection point where wide adoption of RFID will quickly occur.[3,23]

Like so many other aspects of the business world, the enormous impact of Wal-Mart's buying power will dictate how and when consumer goods companies adopt RFID technology. Wal-Mart's impact in the marketplace has been the major impetus for the current buzz about RFID and will spur early adoption. Wal-Mart had a similar impact when they began using barcodes in the 1980s.[12] But Wal-Mart could not have made their decision if many other factors, such as the back-end infrastructure, cost and standard, were not already in place. Companies like Wal-Mart, Tesco, Metro Group, Target and Albertsons will not be able to scale to a trillion dollars in revenue using the limited information provided by barcodes. They have to do it with the next generation of technology, and that is going to be RFID.[2,19] The early successes will not only help an organization, but they will also lay the groundwork for successful future investment in the technology. ■

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Broadband Low Noise Amplifiers							
AML016L2802	0.1 – 6.0	28	±1.25	1.3*	+7	2.0:1	190
AML48L3001	4.0 – 8.0	30	±1.0	1.2	+10	1.8:1	150
AML412L3002	4.0 – 12.0	30	±1.5	1.5	+10	1.8:1	150
AML218L0901	2.0 – 18.0	9	±1.0	2.2	+5	2.5:1	60
AML0518L1601-LN	0.5 – 18.0	16	±1.0	2.7	+8	2.2:1	100
AML0126L2202	0.1 – 26.5	22	±2.25	3.5*	+8	2.2:1	170
AML1226L3301	12.0 – 26.5	33	±2.0	2.8	+8	2.5:1	200
Broadband Medium Power Amplifiers							
AML0016P2001	0.01 – 6.0	21	±1.25	3.2*	+23*	2.0:1	480
AML26P3001-2W	2.0 – 6.0	28	±2.5	6	+33	1.8:1	1500
AML28P3002-2W	2.0 – 8.0	30	±2.0	5.5	+33	2.0:1	2000
AML218P3203	2.0 – 18.0	32	±2.5	4	+25	2.0:1	450
AML618P3502-2W	6.0 – 18.0	35	±2.5	4	+33	2.0:1	1850
Narrow Band Low Noise Amplifiers							
AML23L2801	2.8 – 3.1	28	±0.75	0.7	+10	1.8:1	150
AML1414L2401	14.0 – 14.5	24	±0.75	1.5	+10	1.5:1	130
AML1718L2401	17.0 – 18.0	24	±0.75	1.6	+10	1.8:1	150

Low Phase Noise Amplifiers — **Phase noise (dBc/Hz) at offset**

Part Number	Frequency (GHz)	Gain (dB)	Output Power (dBm)	100Hz	1KHz	10KHz	100KHz
AML811PN0908	8.5 – 11.0	9	17	-154	-159	-167	-170
AML811PN1808	8.5 – 11.0	18	18	-152.5	-157.5	-165.5	-168
AML811PN1508	8.5 – 11.0	15	28	-145.5	-153.5	-158.5	-164.5
AML26PN0904	2.0 – 6.0	9	20	-150	-165	-165	-178
AML26PN1201	2.0 – 6.0	11	15	-155	-160	-160	-175

High Dynamic Range Amplifiers

Part Number	Frequency (MHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	DC
AR01003251X	2 – 32	21	32	52	+28V @ 470mA
AFL30040125	50 – 500	23	28	53	+28V @ 700mA
BP60070024X	20 – 2000	32	30	43	+15V @ 1100mA

*Above 500MHz.

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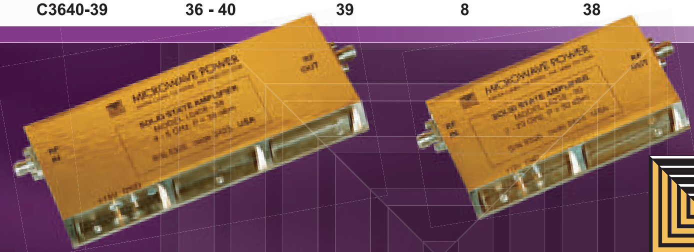
Broadband Microwave Power Amplifiers						
L0104-43	1 - 4	42.5	17.8	41.5	45	14
L0204-44	2 - 4	44	25	42.5	45	14
L0206-40	2 - 6	40	10	38.5	40	8.5
L0208-41	2 - 8	41	12	40	40	17
L0218-32	2 - 18	32	1.4	31	35	5
L0408-43	4 - 8	43	20	41.5	45	17
L0618-43	6 - 18	43	20	41.5	45	22
L0812-46	8 - 12	46	40	45	45	28
Millimeter-Wave Power Amplifiers						
L1826-34	18 - 26	34	2.5	33	35	4
L1840-27	18 - 40	27	0.5	26	30	2
L2240-28	22 - 40	28.5	0.7	27	30	3
L2630-39	26 - 30	39	8.0	38	40	15
L2632-37	26 - 32	37	5.0	36	38	10
L2640-31	26 - 40	31	1.2	30	30	5
L3040-33	30 - 40	33	2.0	32	33	9
L3337-36	33 - 37	36	4.0	35	40	12
L3640-36	36 - 40	36	4.0	35	40	10

High-Power Rack Mount Amplifiers

Model	Frequency (GHz)	Psat (dBm)	Psat (W)	P1dB (dBm)	Pac (kW)	Height (in)
C071077-52	7.1 - 7.7	52.5	170	51.5	1.8	10.25
C090105-50	9 - 10.5	50	100	49	1	8.75
C140145-50	14 - 14.5	50.5	110	49.5	2	10.25
C1416-46	14 - 16	46	40	45	0.35	5.25
C1820-43	18 - 20	43	20	41.5	0.25	5.25
C2326-40	23 - 26	40	10	39	0.25	5.25
C2630-45	26 - 30	45	30	44	0.45	5.25
C3236-40	32 - 36	40	10	39	0.25	5.25
C3640-39	36 - 40	39	8	38	0.24	5.25



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NONLINEAR VECTOR NETWORK ANALYZER APPLICATIONS

Advancements in Vector Network Analysis (VNA) hardware and software algorithms have enabled a new class of instrumentation for analysis of active components. The Nonlinear Vector Network Analyzer (NVNA) performs a variety of measurements for a number of different application areas. These measurement applications are of importance for those designing active components such as amplifiers and in general any component that exhibits nonlinear behavior. The NVNA can also be used to analyze complex signal behavior while applying VNA error correction providing extremely accurate signal analysis capabilities. The NVNA provides vector corrected measurements of the absolute amplitude and cross-frequency phase of frequencies to/from the component with the highest level of accuracy.

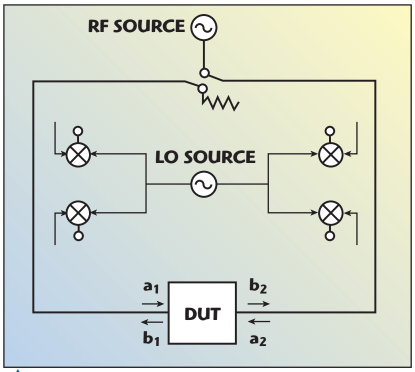

Fig. 1 Schematic of a two-port VNA.

MATHEMATICAL REPRESENTATION OF FREQUENCY SPECTRUM

Generally a VNA measures and displays data in the frequency domain. One example is scattering coefficients (S-parameters) of a component versus frequency. The S-parameters are coefficients of a linear model and are ratios of absolute quantities where the stimulus frequency is the same as the response frequency. ***Figure 1*** illustrates a simplified two-port VNA. The VNA measures the 'a' and 'b' waves at both ports of the component at the same frequency, applies error correction to move the reference plane to the component level, and then typically takes ratios of these waves to generate the S-parameters. However, if a component exhibits nonlinear behavior, there may not be a one-to-one relationship between the input and output frequencies (see ***Figure 2***). In addition, the definition of S-parameters becomes invalid and cannot be used to accurately describe the component behavior. In this case, it is important to accurately measure the vector corrected absolute amplitude of the frequencies and the phase relationship between frequencies (cross-frequency phase) of the 'a' and 'b' waves. Traditional VNAs do not have the ability to accurately measure these characteristics. The NVNA, however, can make these measurements with the highest level of accuracy. Once these absolute quantities are measured, they can then be used to analyze component and complex signal behavior.

NONLINEAR VECTOR NETWORK ANALYZER ARCHITECTURE

The NVNA is based on the Agilent PNA-X

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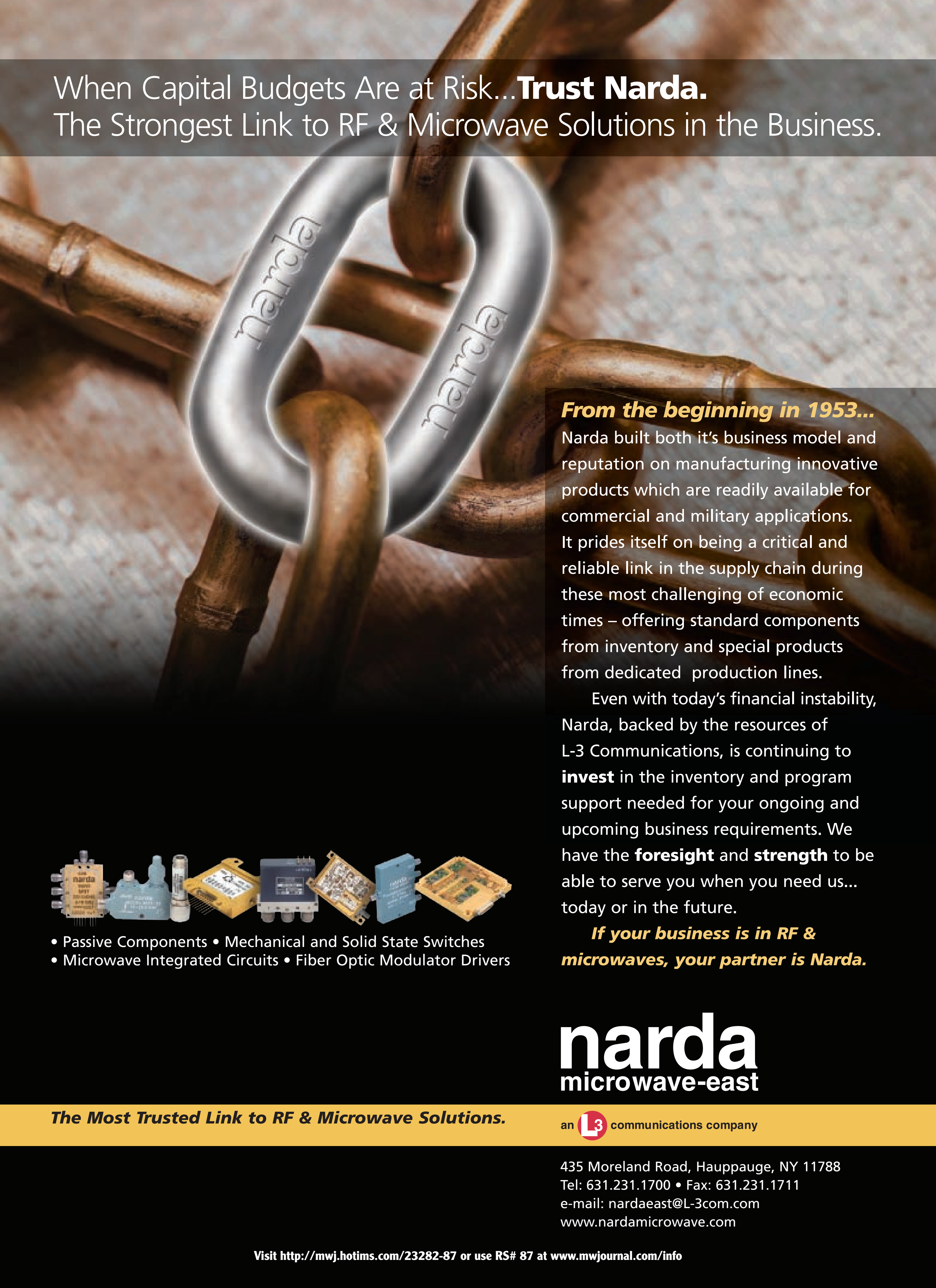
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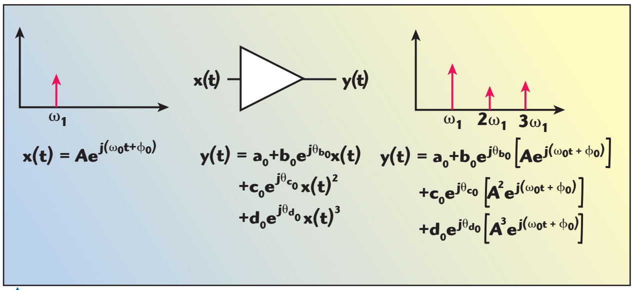
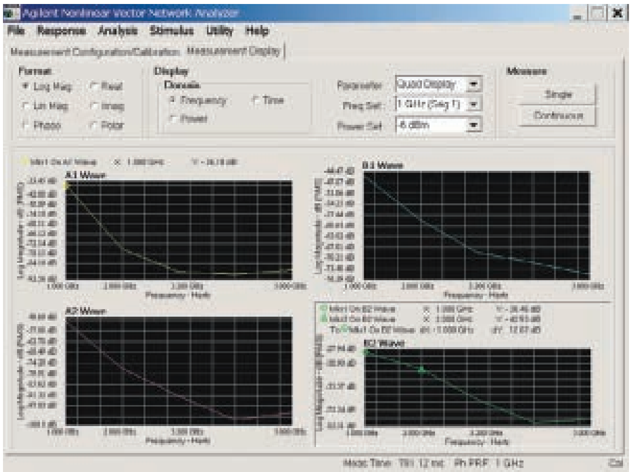


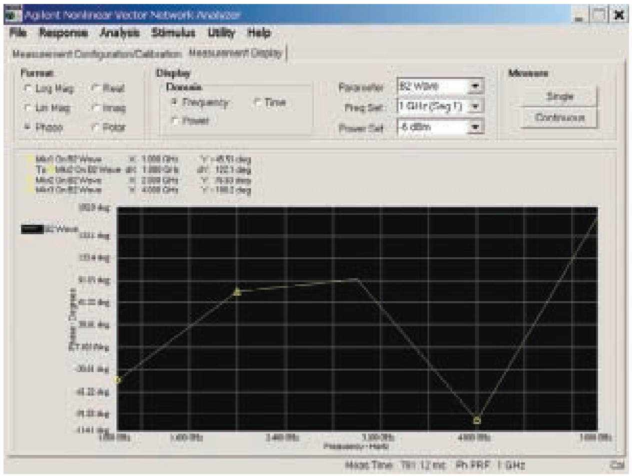
▲ *Fig. 2 Nonlinear component behavior.*

▲ *Fig. 3a Nonlinear vector network analyzer (NVNA).*

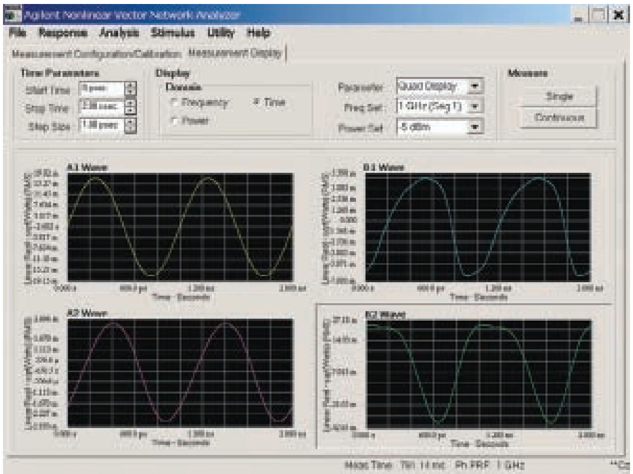
▲ *Fig. 3b New phase calibration standard.*



▲ *Fig. 4a Component amplitude stimulus/response in frequency domain.*



▲ *Fig. 4b Component cross-frequency phase stimulus/response in frequency domain.*



▲ *Fig. 4c Component stimulus/response in time domain.*

series of VNA. It consists of an integrated NVNA firmware application that transforms the PNA-X VNA into the NVNA (see ***Figure 3a***). A simple three-step calibration process using a new phase calibration standard (see ***Figure 3b***), a vector calibration with a vector calibration kit, and amplitude calibration with power sensor, provide the ability to calibrate and measure the vector error corrected absolute amplitude and cross-frequency phase stimulus/response information of components or signals. The PNA-X can be switched to the standard VNA mode or the NVNA mode simply by running the integrated application of choice on the instrument.

The new phase calibration standard provides the means to acquire error corrected cross-frequency phase information from the component that is traceable to standards labs. It operates over the frequency range of the PNA-X and has the ability to generate a frequency grid spacing of less than 1 MHz. This grid spacing sets the minimum frequency step for the measurements. It is very insensitive to temperature, input power and drive frequency providing stable and accurate measurements and calibration.

A segment table in the NVNA provides the ability to generate a multi-dimensional stimulus/response sweep.

As an example, a sweep plan can be configured where the RF stimulus is swept from 1 to 2 GHz over 11 points, the RF power swept from -20 to +10 dBm over 31 points, and the receivers configured to measure 5 harmonics at each of the stimulus settings. This means there are a total of 11 × 31 × 5 = 1705 measurement points. The NVNA also can control external instrumentation synchronously with the RF measurements to read parameters such as DC voltage and current.

NONLINEAR VECTOR NETWORK ANALYZER MEASUREMENT APPLICATIONS

The NVNA has a number of new measurement applications. All of these measurement applications have the highest degree of accuracy since vector error correction is applied thus removing the systematic measurement errors such as impedance mismatch and loss. The NVNA enables these applications due to the ability to relate the amplitude and phase (cross-frequency) between the stimulus/response frequencies that are measured with this error correction applied.

Absolute Amplitude and Cross-frequency Phase

The NVNA can measure the vector corrected absolute amplitude and cross-frequency phase stimulus/response information from the component. ***Figures 4a*** and ***4b*** illustrate a measurement of an amplifier driven into compression with a 1 GHz stimulus at -6 dBm. The 'a1' wave is the incident wave applied to the component, which shows a very large response at the 1 GHz fundamental frequency and very low responses at the harmonics. This is because the source harmonics from the PNA-X source are well below -60 dBc. The 'b2' wave, which represents the output from the component, contains harmonic content due to the nonlinear behavior of the component. The vector corrected absolute amplitude can be measured as well as the phase relationships between all the frequencies. As an example, the cross-frequency phase between the fundamental and second harmonic on the 'b2' wave is shown to be 122.1°. Since the amplitude and cross-frequency phase of all the frequency spectra is accurately known, an inverse Fourier transform can be applied to the frequency domain data to generate the time domain waveforms, as shown in ***Figure 4c***.

Vector Corrected Time Domain Scope

The NVNA can be used as a vector corrected time domain scope by measuring the absolute amplitude and cross-frequency phase of the signals with error correction applied. Measurements are made in the frequency domain and an inverse Fourier transform is applied to get the time domain waveforms. The NVNA with the N5242A PNA-X can sweep from 10 MHz to 26.5 GHz. The NVNA can then be used as a vector corrected time domain scope with 26 GHz of detection bandwidth. A general 'rule-of-thumb' is that the resolution in the time domain at each discrete point is inversely proportional to the swept bandwidth (1/(26 GHz) ≈40 ps). ***Figure 5*** illustrates a measurement of an amplifier driven into compression. The yellow trace is the input sinusoidal voltage waveform at the component terminals and the blue trace is the compressed output voltage waveform. The output waveform is distorted due to the presence of high harmonic levels that are generated by the component.

RF I/V Curves

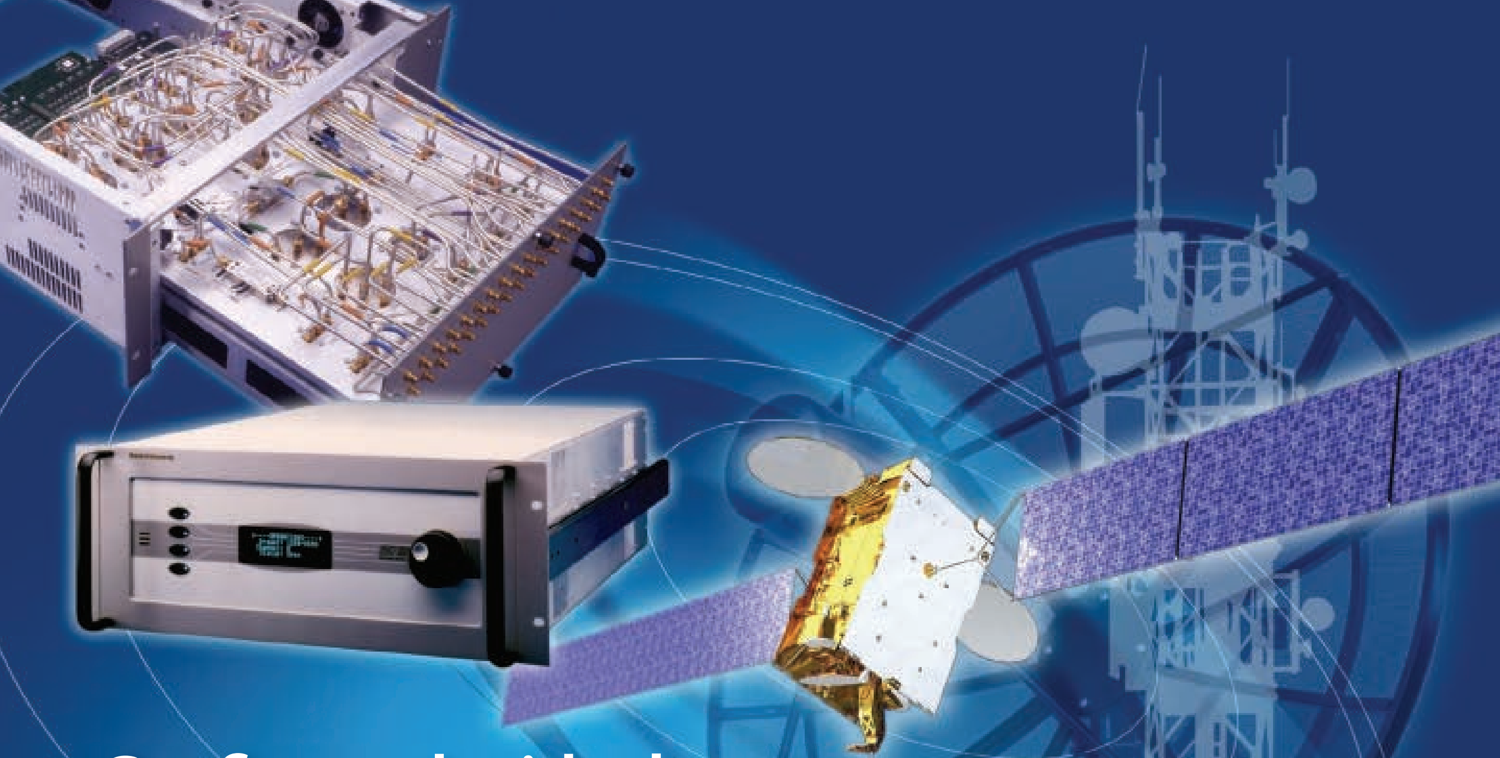
Often, RF I/V curves are used to analyze linear and nonlinear characteristics of a component, such as an amplifier. These curves are often superimposed on the DC I/V curves (which set the component operating point) and provide the designer important information on the component behavior under various DC bias and RF conditions. An example would be measuring the time varying drain voltage (Vd) in conjunction with the time varying drain current (Id). At each instance in time, the drain voltage and current are compared and displayed as in ***Figure 6***. These voltage and currents are calculated based on the measured 'a' and 'b' waves as in Equation 1.

$$V_i = \sqrt{Z_0}\left(a_i^1 + b_i^1\right)$$

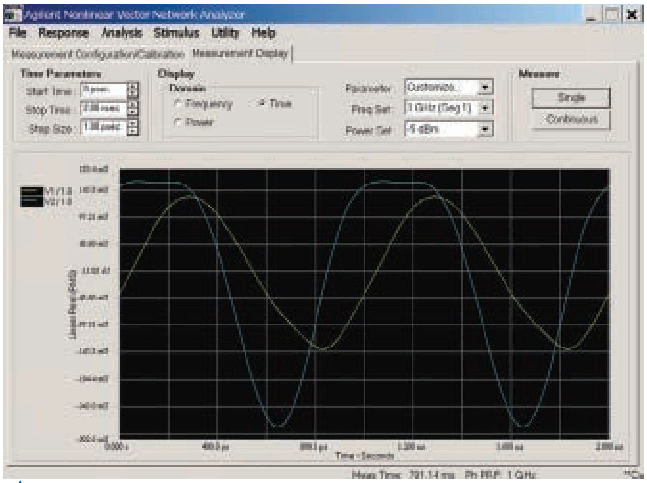
$$I_i = \frac{\left(a_i^1 - b_i^1\right)}{\sqrt{Z_0}} \qquad (1)$$

Multi-tone Stimulus/Response

In some scenarios a multi-tone stimulus is likely to be applied to the



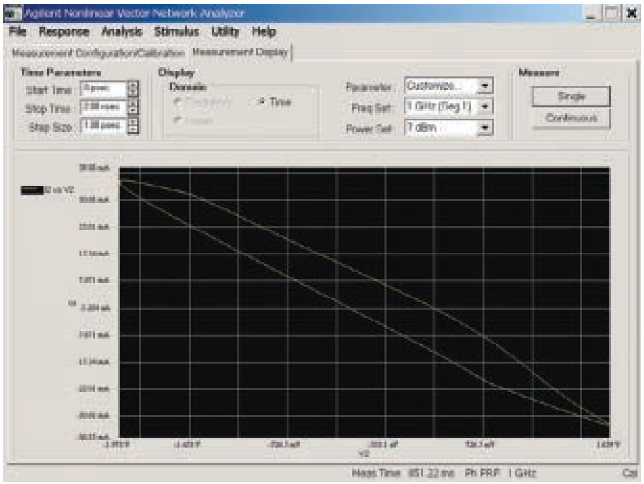
component to subject it to a spectrally rich stimulus thus exciting more nonlinear behavior. ***Figure 7*** illustrates a measurement of an amplifier with an input stimulus of 5 frequencies, spaced 10 MHz apart and centered at 1 GHz. The NVNA measured the entire resulting spectrum (multi-tone and inter-modulation products at the fundamental and harmonics) out to 26 GHz, and then performed an inverse Fourier transform to get the time domain response. Nonlinearity is clearly evident when comparing the 'a1' waveform envelope (input stimulus) to the 'b2' waveform envelope (output response) of the amplifier.



▲ *Fig. 5 Component stimulus/response voltages in time domain.*

Fast RF and DC Pulses

The NVNA can be used to analyze complex signals. To illustrate this application a very narrow DC and RF pulse is measured. To visually generate what the spectrum of a pulsed signal looks like, the time domain response is first mathematically analyzed. Equation 2 (time domain view of pulsed signal) illustrates the time domain relationship of a pulsed signal. This is generated by first creating a rectangular windowed version (rect(t)) of the signal with pulse width (PW). A comb function is then realized consisting of a periodic train of impulses spaced 1/PRF apart where PRF is the



▲ *Fig. 6 Component RF I/V response.*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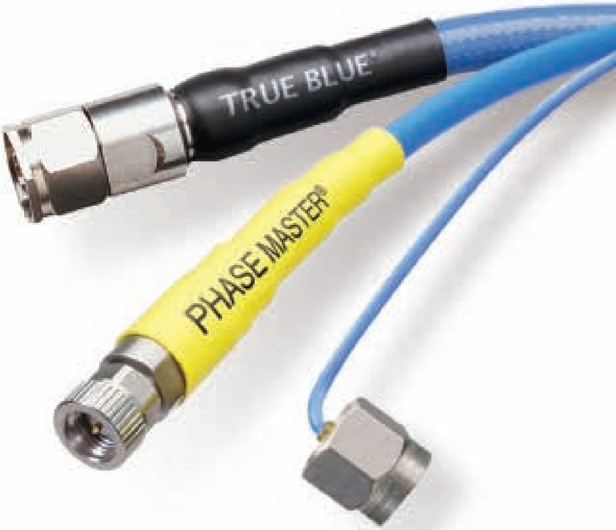
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pulse repetition frequency. This can also be viewed as impulses at spacing equal to the pulse period. The windowed version of the signal is then convolved with the comb function to generate a periodic pulse train in time corresponding to the pulsed signal, as illustrated in ***Figure 8***.

$$y(t) = \left[\mathrm{rect}_{pw}(t)x(t)\right] * \mathrm{comb}_{\frac{1}{prf}}(t) \tag{2}$$

Equation 3 (Fourier transform of time domain pulsed signal) illustrates that the frequency domain spectrum of the pulsed signal is a sampled sinc function with sample points (signal present) equal to the pulse repetition frequency (from the comb function).

$$Y(s) = \left[pw \cdot \mathrm{sinc}(pw \cdot s) * X(s)\right]\left[prf \cdot \mathrm{comb}(prf \cdot s)\right]$$

$$Y(s) = \left[\mathrm{DutyCycle} \cdot \mathrm{sinc}(pw \cdot s) \cdot \mathrm{comb}(prf \cdot s)\right] * X(s) \tag{3}$$

Figure 9 shows what the pulsed spectrum would look like for a signal that has a pulse repetition frequency of 2.5 GHz and a pulse width of 40 ps with no carrier modulation (pulsed DC). Notice that the spectrum has components that are n x PRF away from the modulated signal (DC or RF). If it is pulsed DC then the spectrum is centered on DC (X(s) = DC). If it is pulsed RF, the spectrum is centered on the pulsed RF carrier (X(s)). It also contains null points that are spaced n/PW. Extremely narrow pulse measurements are possible with the NVNA due to its 26 GHz of vector corrected detection bandwidth, which corresponds to a minimum resolution in the time domain of approximately 40 ps.

Figure 10 shows a measurement of a DC pulse with PW less than 50 ps. ***Figure 11*** illustrates an RF pulse measurement where the pulse width is 10 ns and the carrier frequency 2 GHz. ***Figure 12*** shows the measurement of a square wave.

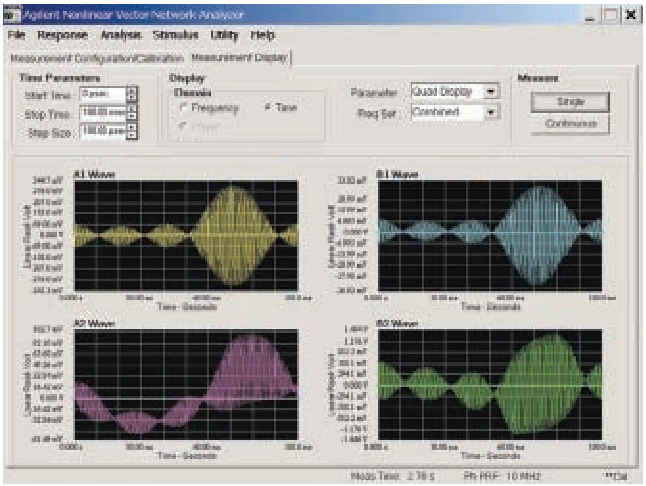


Fig. 7 Component amplitude response in time domain with multi-tone stimulus.

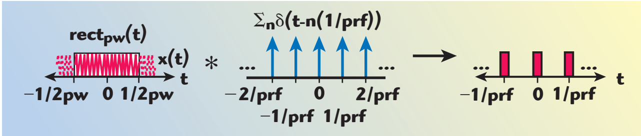
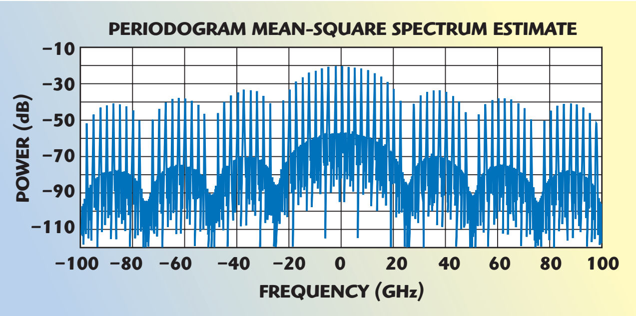


Fig. 8 Time domain representation of a periodic pulsed DC signal.

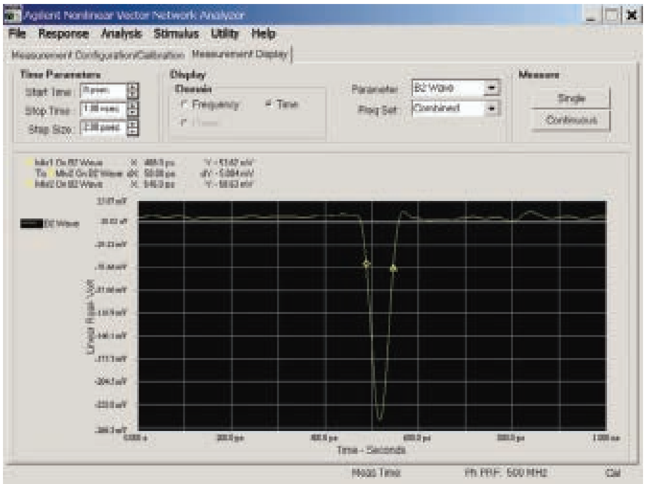
Another possible measurement would be multipath responses in an antenna chamber when measuring the RCS of an object.

Multi-envelope Domain

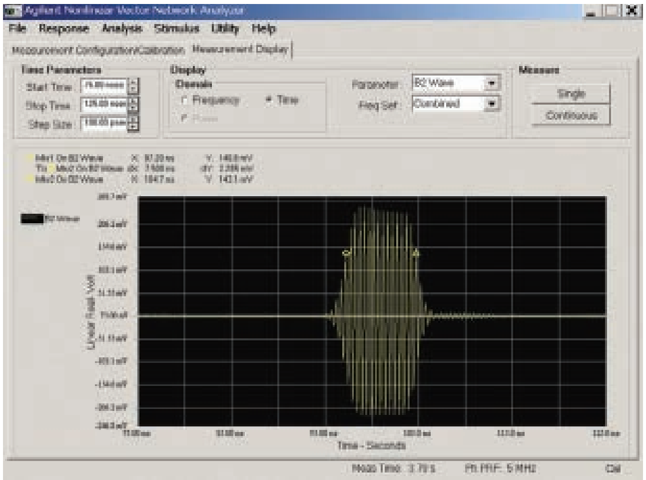
A nonlinear component may exhibit dynamic memory effects. Memory effects in an amplifier can cause distortion that is undesirable. To measure and analyze memory effects, a multi-envelope measurement can be performed where the component is stimulated with a pulsed signal (RF and/or DC bias) and the resulting envelope 'a' and 'b' waveforms are measured at the fundamental and harmonics frequencies. The envelope amplitude and phase can be analyzed versus time at each of the spectral components. If the component exhibited no memory effects, then the envelopes from the component would not have a time varying phenomena (that is the envelope would be flat). ***Figure 13*** shows an amplifier that exhibits both nonlinear behavior and memory. A 1 GHz pulsed RF stimulus was applied to the component with a pulse width of 100 us. Harmonics are generated by the component due to its intrinsic nonlinearities. Each fundamental and harmonic has a distinct envelope profile due to the dynamic memory effects in the amplifier. Short-term memory dynamics as seen at the beginning of the pulse may be caused by bias network memory and longer term slopes in the envelope may be caused by thermal memory. The NVNA can measure down to envelope resolutions of 16.7 ns in standard mode.



▲ *Fig. 9 Frequency domain of periodic pulsed DC signal.*



▲ *Fig. 10 Measurement response of a pulsed DC signal in time domain.*



▲ *Fig. 11 Measurement response of a pulsed RF signal in time domain.*

X-PARAMETERS

A typical VNA can measure scattering coefficients of a component often called S-parameters. Equation 4 illustrates the S-parameter model and equations for a two-port component.

$$b_1 = S_{11}a_1 + S_{12}a_2$$
$$b_2 = S_{21}a_1 + S_{22}a_2 \qquad (4)$$

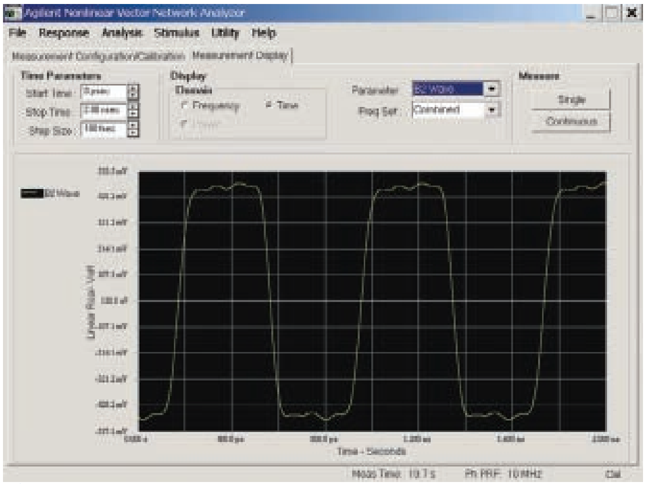
The S-parameters describe the linear behavior of the component and can then be used to design predictable linear systems. When measuring a component that exhibits nonlinear behavior the definition of the linear scattering model is no longer valid. In such a case, where the component has multiple input and output frequencies, due to linear and nonlinear behavior, a new model must be generated that encompasses both the linear and nonlinear characteristics of the component. Equation 5 shows this new model with scattering coefficients called X-parameters (LSOP = Large Signal Operating Point).

$$b_{ij} = X^F_{ij}(LSOP)P^j + \sum_{k,l\neq 1,1}[X^S_{ij,kl}(LSOP)P^{j-1}a_{kl} + X^T_{ij,kl}(LSOP)P^{j+1}a^*_{kl}] \qquad (5)$$

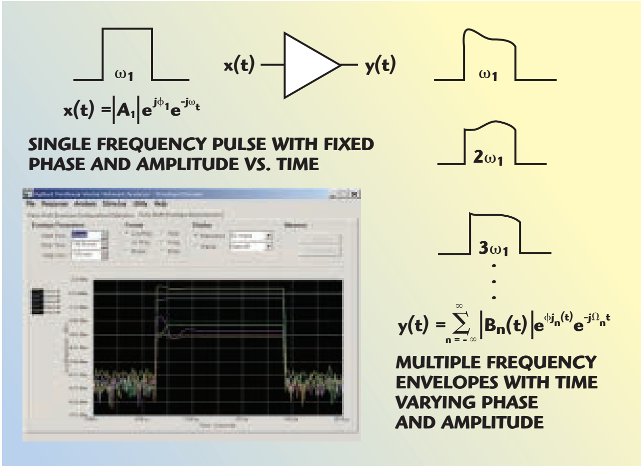
i = output port index
j = output frequency index
k = input port index
l = input frequency index

The X-parameters are the logical, mathematically correct extension of S-parameters into a nonlinear large-signal operating environment. The X-parameters fully describe the input and output frequency mapping of the component and/or system thus completely describing the linear and nonlinear behavior. The NVNA measures the X-parameters of the component that can be displayed as well as imported into Agilent ADS as a fully operational linear and nonlinear model for optimization, simulation and design.

The X-parameters can provide information such as the component gain and match, while the component is operating in a linear or nonlinear state. The X-parameters can then be displayed like S-parameters (see ***Figure 14***). Since the X-parameters relate cross-frequency dependences, there can be many more X-parameters than S-parameters. As an example, the response of the output fundamental to the input third harmonic input is X21,13. In addition, X-parameters depend explicitly on the large-signal state of the component, so input power may be a variable, unlike S-parameters that



▲ *Fig. 12 Measurement response of a square wave signal in time domain.*



▲ *Fig. 13 Component multi-envelope domain response.*

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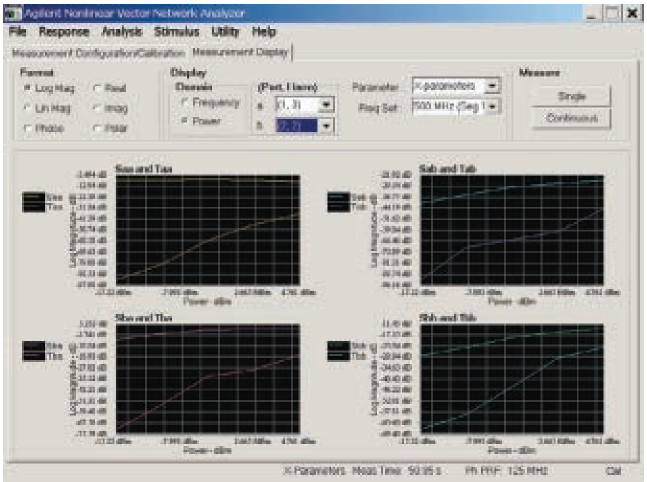
are assumed to be power independent. Possibly one of the strongest benefits of X-parameters is the ability to accurately cascade the X-parameters from individual components using ADS to design and simulate more complex modules and systems.

The usefulness of the X-parameters can be illustrated in the process of designing a power amplifier. The designer is compelled to drive the amplifier into the nonlinear region to get the maximum output power as well as to extract the maximum efficiency. Some form of a feedback circuit is then used to compensate for the nonlinear effects and make the output behave like a high power linear component. A typical approach is to suppress the harmonic outputs of a power amplifier using filters and other components. If the input match of the filtering components is not appropriately matched to the output match of the specific harmonic of interest generated by the amplifier, then the attenuation level of that specific harmonic could be significantly different than anticipated. This leads to a time consuming iterative design experience where the maximum performance of the component may never be fully realized. With accurate phase and amplitude information from the X-parameters and using simulation tools, designers can design the most robust systems possible in the shortest amount of time, with the highest degree of accuracy.



▲ *Fig. 14 Component X-parameter behavior.*

CONCLUSION

The NVNA has enabled a number of new measurement applications. Component behavior and complex signal analysis can be analyzed in the time, frequency and power domains with vector error correction applied. Memory effects can be analyzed utilizing the multi-envelope domain and the new nonlinear scattering coefficients (X-parameters) can be measured and then used for design and analysis of active components and systems. ■

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DEVELOPING STRATEGIES FOR MIMO TESTING

Limited bandwidth and the need to support a growing number of wireless services have opened the way for the use of non-traditional techniques in communications systems for increased data capacity. One of these techniques is the use of multiple-input, multiple-output (MIMO) system configurations, in which multiple antennas are employed. The greater complexity of MIMO systems compared to conventional single-channel architectures makes testing these systems challenging, requiring special equipment and methodologies. This article will describe different types of MIMO measurements, including an approach for including channel impairments such as noise and interference.

Increased data throughput is critical to the success of future mobile wireless services that promise reliable voice, data and video access. Although the data throughput of a communications channel can be increased by increasing the channel's bandwidth, bandwidth is generally licensed and limited. A more practical approach lies in the adoption of advanced modulation formats, such as orthogonal frequency-division multiplexing (OFDM) and novel communications system architectures, such as multiple-input, multiple-output (MIMO) configurations. A MIMO system uses multiple antennas and the spatial diversity between them to increase data throughput without increasing bandwidth. The added system complexity, however, poses new requirements for test equipment and measurement strategies, which can best be satisfied through the use of modular measurement systems and specialized test software.

High data throughput has been a guiding requirement for many recent wireless communications standards, with provisions for the use of MIMO in a number of these newer standards, including IEEE 802.11n WLAN, IEEE 802.16e mobile WiMAX Wave 2 and 3GPP Long Term Evolution (LTE). These systems couple MIMO with the use of OFDM or orthogonal frequency division multiple access (OFDMA) modulation to achieve significant increases in data throughput without increasing the channel bandwidth.

SISO VS. MIMO

In a conventional single-input, single-output (SISO) communications system (see ***Figure 1a***), such as a standard IEEE 802.11a/b/g wireless local area network (WLAN) system, a radio link uses a single transmitter and receiver. It may have multiple antennas at each end of the communications link, but only one set of antennas is used at one time and a single channel carries a single stream of data. In an ideal communications channel, radio signals would travel a single path from transmit antenna to receive antenna. But obstructions (such as buildings and terrain) and propagation effects in the radio channel create multipath effects. As a result, multiple signals arrive at the re-

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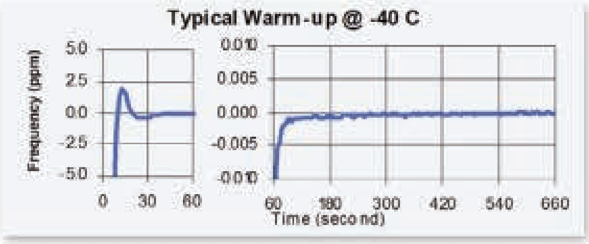

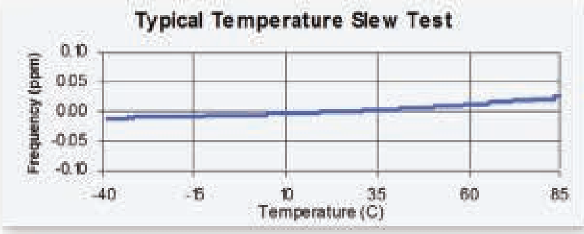

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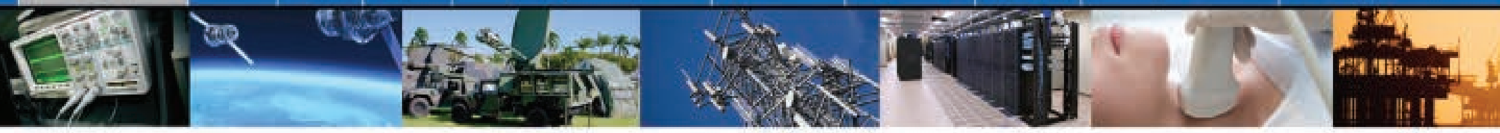

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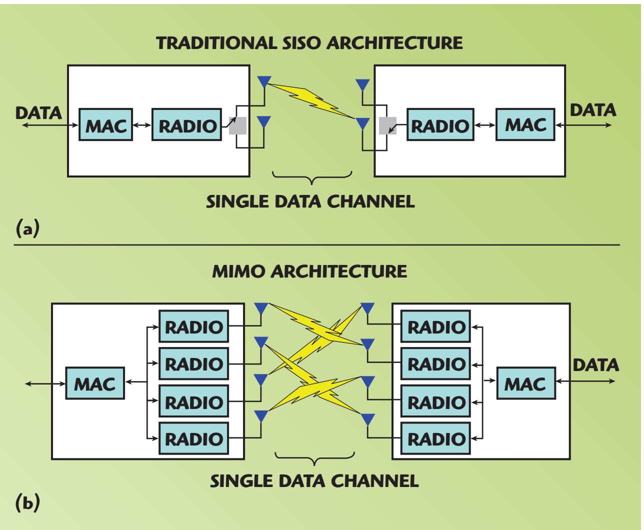
ceive antenna. The reflected signals suffer losses due to fading and delays due to longer path lengths than the direct-path signals. Due to differences in path lengths, the phases of these reflected signals are also different than those of direct-path signals. Because of this, signals at the receiver can combine constructively or destructively, causing fluctuations in received signal strength at the receiver. Excessive multipath effects can diminish the data throughput or cause lost data.

Because OFDM is often teamed with MIMO approaches to increase data throughput in a given communications channel, it is important first to understand OFDM before exploring MIMO concepts. For example, OFDM is used in IEEE 802.11g (WiFi) and IEEE 802.16e WiMAX systems. As with MIMO, OFDM can yield an increase in data throughput without an increase in channel bandwidth or an increase in the order of the modulation scheme, such as from a 16-state quadrature-amplitude-modulation (16QAM) approach to a 64-state QAM (64QAM) system.

OFDM essentially employs wireless signals comprised of a series of orthogonal subcarriers. The subcarriers are spaced for optimum isolation from each other, so that the maximum power of a given modulated subcarrier corresponds with the zero crossing point or minimum power of the adjacent modulated subcarrier. The data to be communicated is multiplexed across the multiple subcarriers, with some subcarriers serving as guard bands for isolation and to prevent adjacent-channel interference. For added robustness, many communications standards using OFDM include a small fading interval to allow time for multipath signal components to fade so that they do not interfere with the reception of the next transmitted symbol.

By processing OFDM subcarriers with digital signal processing based on the use of an inverse Fourier transform, they can be combined into a single stream and the data is recovered. Because multiple streams can be transmitted in parallel over a single channel while preserving their relative phase and frequency relationships, high data throughput is possible without extending bandwidth.

In contrast with a SISO communications system, a MIMO system (see ***Figure 1b***) uses multiple radios and antennas simultaneously, with multiple data streams carried over a single communications channel. The multiplexing of these data streams is coordinated by the medium access control (MAC) layer at both ends of the communications link. MIMO systems do not require a symmetrical arrangement of antennas, such as two transmit and two receive antennas (2 × 2) or four transmit and four receive antennas (4 × 4); they can also operate in "unbalanced" configurations, such as with four transmit antennas and three receive antennas in a 4 × 3 configuration.



▲ *Fig. 1 Traditional radio link based on SISO configuration (a) and MIMO configuration (b).*

To increase the data throughput of a SISO system, a more complex modulation format, or additional bandwidth, or a combination of the two is required. Quite simply, to double the data throughput of a SISO system channel, the channel bandwidth must also be doubled. To increase the data throughput of a MIMO system, the number of transmitters, receivers and their antennas is increased. Through the use of multiple antennas and spatial multiplexing among the signal propagation paths, a MIMO system can increase capacity by a factor of about 3.5 without increasing channel bandwidth.

A MIMO system takes advantage of variations in the received signals to increase data throughput. Received signals are treated as simultaneous equations with unknowns (the transmitted symbols). Greater variations in the multiple signal paths simplify the solution of these simultaneous equations, resulting in increased data throughput.

How does the channel capacity of a SISO communications channel compare to that of a MIMO communications channel? Shannon's equation for the theoretical throughput of a communications channel can be applied in the SISO case:

$$C=B\log_2(1+S/N) \quad (1)$$

where:

C = the channel capacity (in bits per second),

B = the bandwidth (in Hertz),

S = the total signal power over the bandwidth [in Watts or Volts squared (V^2)], and

N = the total noise power over the bandwidth [in Watts or Volts squared (V^2)].

When this equation is modified for MIMO applications,

$$C=AB\log_2(1+S/N) \quad (2)$$

where:

A = the number of transmit antennas

The equation points out the direct correlation between the number of transmit antennas in a MIMO system and the resulting channel capacity. A MIMO system transmits multiple bit streams across the same physical channel using multiple transmit antennas by using a technique known as spatial multiplexing. The bit stream is multiplexed to multiple transmitters without changing the symbol rate of each independent transmitter. By adding more transmitters and transmit antennas, the system throughput increases without changing the channel bandwidth.

Modeling the communications channel of a MIMO system must take into account the multiple data streams, including the direct and reflected signals arriving at each receiver. By using a convention in which the multiple transmitters are identified as Tx1, Tx2...Txn for n number of trans-

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mitters, and the similar convention of Rx1, Rx2...Rxn for n number of receivers, a MIMO communication can be represented in the form of a matrix of signal vectors (h_{xy}) where x designates the number of the transmitter and y is the number of the receiver. For example, h_{21} is the signal from transmitter 2 to receiver 1, while h_{22} is the signal from transmitter 2 to receiver 2 (see ***Figure 2***). With these conventions, a MIMO channel can be modeled as

$$y=H*x+n \tag{3}$$

where:
y = the receive signal vector,
H = the channel matrix (of h_{xy} signal elements),
x = the transmit signal vector, and
n = the noise vector.

Different channel effects on received signals, such as fading and multipath, can be corrected through this same matrix algebra approach, using the relationship

$$Rx=H*Tx+n \tag{4}$$

where Rx represents the matrix of Rx_1, Rx_2...Rx_n receive antennas and Tx represents the matrix of Tx_1, Tx_2...Tx_n transmit antennas. For a 2 × 2 MIMO system, this relationship would appear in matrix form, as shown in Figure 2.

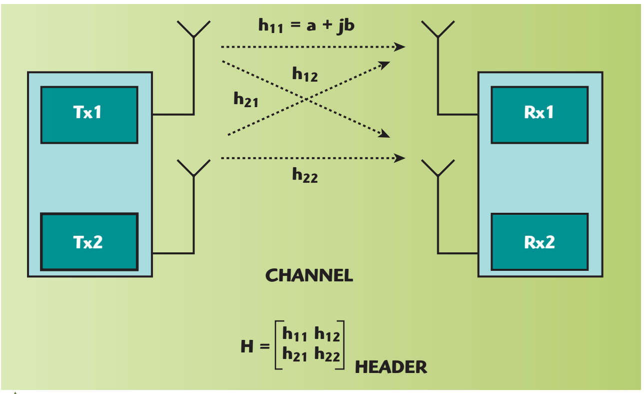
$$H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}_{\text{Header}} \tag{5}$$

The signals in these relationships consist of amplitude, frequency and phase components, making it practical to represent them as vectors. Similarly, it is also practical to represent these signals in a measurement system as vector signals.

MEASUREMENT CHALLENGES

The increases in data throughput from MIMO techniques come with added system complexity that results in challenges when designing test equipment and measurement systems for evaluating the performance of MIMO systems and the components in those systems. Before deciding on the type of test equipment best suited for MIMO measurements, it might make sense to determine the type of measurements needed for characterizing the performance of a MIMO communications channel. MIMO measurements can generally be categorized as system-level measurements and channel-response measurements, as well as functional measurements for the components used in a MIMO system.

It has already been noted that MIMO signals are defined by their frequency, amplitude and relative phase, and



▲ *Fig. 2 A radio channel in a MIMO system can be modeled as a number of different vector quantities.*

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IKE Micro owner Scott MacKenzie discusses his latest fashion choices.

MWJ: I guess the first obvious question is, why the outfit?

SM: I promised to dress up like a woman if we beat our productivity goal in 2008. We did, so here I am in all my glory!

MWJ: How does IKE Micro produce at such a high level?

SM: We have a veteran, low-turnover workforce, and a good balance of automated and manual assembly capability. Because of our 100% focus on build-to-print manufacturing, design and market issues don't get in the way of the delivery schedule.

MWJ: Are your company's assembly capabilities comprehensive?

SM: Yes, from DC to 100GHz. Our capabilities include surface mount, epoxy and solder board mount, feedthru installation, die attach, wire/ribbon bond, coil and beam lead bonding, and all the crazy RF soldering and bonding needed so our units make it through test with minimal tuning.

MWJ: What types of customers take advantage of IKE's experience and capabilities?

SM: It's a good mix. It includes the big systems companies and many of the small to mid-sized module suppliers. Many of these companies advertise with you. We do complex modules and pretty basic subassemblies. Our domestic and international customer mix is 65% defense and 35% commercial.

MWJ: What are your goals for 2009?

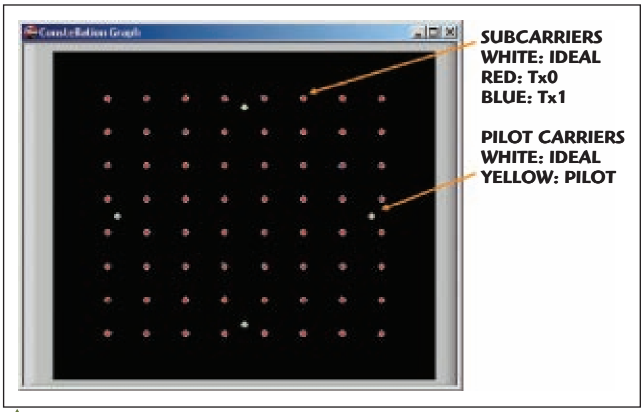
SM: I want to continue to produce at high levels and exceed customer expectations. More importantly, I plan to steer clear of the EE design guys, some of those guys freak me out, especially when I'm wearing this dress.

measurements of MIMO signals must determine the accuracy and fidelity of those three signal characteristics. In addition, MIMO systems are often based on downconversion of received signals to a zero intermediate frequency (zero-IF) with baseband in-phase (I) and quadrature (Q) signal components. For high modulation accuracy, the fidelity of the I and Q signal components must be preserved, requiring high performance and minimal distortion from all components in the signal path, including amplifiers, filters, mixers, and I/Q modulators and demodulators.

In many wireless systems, error vector magnitude (EVM) is a standard parameter for evaluating performance and is highly useful for MIMO systems as well. EVM, which is also known as the received constellation error (RCE) because it is graphically shown on a constellation diagram, is essentially the vector difference between ideal signals and measured signals and can be used as a direct measure of the modulation accuracy and overall signal quality of a MIMO transmitter and the performance of a MIMO receiver. An EVM measurement captures a signal's amplitude and phase errors and reduces the many parameters that characterize distortion of a transmitted RF signal into one parameter that allows comparison of different transmitters. Additional key MIMO transmitter tests include evaluation of group delay and variations in group delay, phase noise, amplifier compression and I/Q mismatches in signal-processing components. Signal distortion caused by these effects will generally be noticeable on an EVM constellation diagram.

In an EVM constellation diagram, an ideal signal would have all constellation points sharply defined at their ideal locations. But signal and component imperfections, such as phase noise and carrier leakage, cause these constellation points to shift from their ideal locations. EVM is a measure of these deviations from the ideal. In addition to overall EVM as a MIMO system test parameter, EVM as a function of frequency and EVM as a function of time can provide insights into transmitter performance when assessing MIMO channel behavior. In addition, EVM displayed versus subcarrier and symbol can offer further details on a MIMO transmitter's performance.

Sharply defined points in an EVM constellation diagram indicate good MIMO system performance. In an example measurement of a 2 × 2 MIMO system with OFDM and 64QAM, color is used to differentiate the different transmitter signals as well as the pilot carriers. In the constellation diagram shown in ***Figure 3***, red and blue dots rep-



▲ *Fig. 3 An EVM constellation diagram provides a graphical indication of potential MIMO system problems.*

resent the two transmit signals, Tx0 and Tx1, in the 2 × 2 MIMO system. They are overlaid on white dots, which represent the ideal locations for the subcarriers. Pilot carriers are shown by yellow dots, which are overlaid on white dots representing ideal pilot carrier locations.

Such a color-coded diagram makes it a simple matter to identify transmit signal problems. For example, red or blue subcarrier constellation points that were significantly offset from the ideal white points would indicate an I/Q imbalance, while a fuzzy appearance to the points would result from the effects of noise on the transmitted signals. A donut-shaped appearance to the constellation's points would be a sign of excessive phase noise.

In terms of more conventional X-Y type plots of performance, measurements of channel metrics basically show the health of the signal matrix in a MIMO system, plotting matrix condition versus subcarrier. The plot shown in ***Figure 4***, that

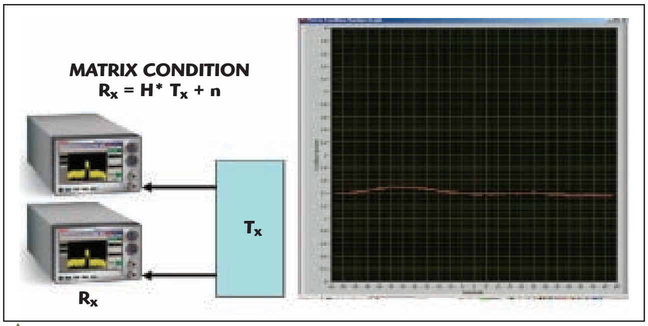


Fig. 4 Plotting condition number as a function of subcarrier shows the orthogonality of a MIMO channel's subcarrier.

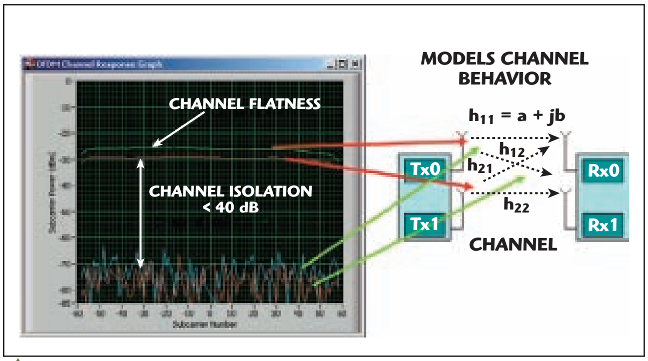


Fig. 5 The channel flatness and isolation can be evaluated by directly connecting MIMO transmitters to receivers.

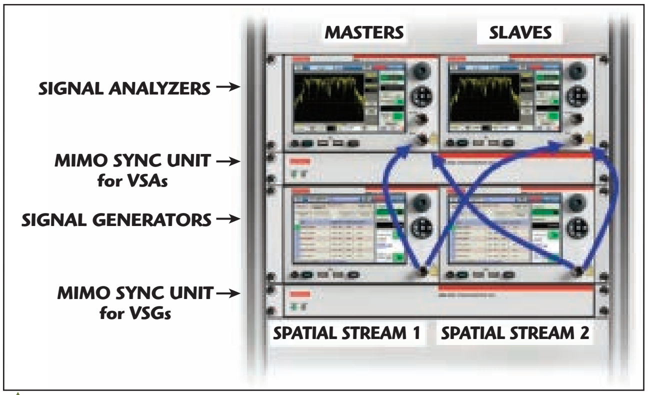


Fig. 6 Example of MIMO test system using multiple VSGs, VSAs and synchronization units (computer controlled).

is a measure of the system's capability to invert the channel and solve for the transmitted symbols, can be used to determine the orthogonality of each stream in the MIMO system. By transmitting inverted symbols, the coverage of the system can be analyzed. By transmitting parallel symbols, the system throughput can be evaluated.

Channel response measurements showing subcarrier flatness as a function of subcarrier number can shed light on the MIMO channel behavior. In example measurements made on an IEEE 802.16e OFDM channel as shown in ***Figure 5***, the green trace shows the power of the signal from the first transmitter (Tx0) to the first receiver (Rx0); the upper red trace represents the signal from the second transmitter (Tx1) to the second receiver (Rx1) in a 2 × 2 MIMO system. The blue trace shows the signal from the first transmitter (Tx0) to the second receiver (Rx1) and the bottom red trace shows the signal from the second transmitter (Tx1) to the first receiver (Rx0). The power level versus subcarrier indicates channel flatness, while the difference between the first and indirect signals shows channel isolation (less than 40 dB in this example). These measurements were made by connecting transmitters directly to receivers with coaxial cables.

A number of measurements over time and over time and frequency can be used to show MIMO performance characteristics that may change under different conditions. For example, measurements of EVM versus OFDM symbol time help identify problems with interference or performance variations with time. Measurements of EVM versus subcarrier can be used to analyze in-channel effects of noise, such as spurious. Measurements of power versus OFDM symbol time can isolate in-band amplitude deviations. Measurements of frequency versus OFDM symbol time can be used to check frequency accuracy, isolating problems such as frequency drift over the duration of a packet.

HARDWARE CONSIDERATIONS

A test system for making MIMO measurements must accurately emulate the operation of the MIMO system, with the capabilities of generating signals with known frequency, amplitude and phase characteristics, and then capturing and analyzing those signals from a device under test (DUT). The test system must support the modulation formats of interest as well as the full modulation bandwidth of the system under test. For generating test signals, an arbitrary waveform generator or vector signal generator (VSG) provides the control needed to create practical test signals, while a vector signal analyzer (VSA) can serve as the test receiver. Any test system designed for MIMO testing should provide the required number of test signal sources and signal analyzers to match the transmitters and receivers in the system to be tested, and should be scalable to meet future requirements. For instance, the MIMO test system provided by Keithley Instruments is scalable from stand-alone VSGs and VSAs up to an 8 × 8 channel system and is flexible enough to handle any combination of sources and analyzers within that range.

Given that synchronization of multiple sources and analyzers is essential to achieving meaningful MIMO measurements, a common reference oscillator is needed for these instruments. For example, in the 2 × 2 MIMO measurement system shown in ***Figure 6***, dedicated synchronization units are used for the multiple VSAs and VSGs. These units distribute common signals such as a local oscillator, common clock, and precise trigger, that provide for low sampler and RF carrier phase jitter, which is necessary for the most accurate and repeatable measurements required by OFDM MIMO signals. In particular, the synchronization unit provides for less than one degree of peak-to-peak jitter.

The effectiveness and ease of use of any MIMO test system also depends on the system's test software. With the growing adoption of MIMO techniques in wireless communications systems, off-the-shelf test software solutions are commonly available for simplifying system and channel measurements. For example, Keithley's SignalMeister™ RF Communications Test Toolkit software provides both complex signal generation and signal analysis capability for MIMO applications like WLAN 802.11n and WIMAX 802.16e Wave 2. In addition to extensive EVM and MIMO channel response measurements, this software can also be used to evaluate SISO systems.

The test equipment and measurements discussed so far apply to evaluating the performance of systems and their components for MIMO communications, typically under ideal conditions. But how well will a MIMO system perform under impaired signal conditions? In that case, a different type of test system is required, known as a channel emulator. It provides the means to exercise a MIMO system and its components with such channel impairments as signal fading, additive white Gaussian noise (AWGN), co-channel interference, and even Doppler effects, the type of problems that might be experienced by a mobile unit in a vehicle in motion relative to a base station.

A channel emulator must act as the transmitter and receiver in a MIMO system, but must also have the capabilities of attenuating signals and adding delays to model real-world conditions. A suitable channel emulator will also provide software-defined channel models, such as ITU M.1225 A and B profiles for WiMAX. A practical channel emulator should exceed the performance of the system that it is testing with full automation capabilities for manufacturing testing when needed. The emulator should also be bidirectional in function so that it can support channel models for both uplink and downlink testing. By also supporting calibrated reciprocal tests, the emulator will be useful in testing MIMO systems employing advanced beam-forming techniques. Finally, although the examples presented in this article have applied to 2 × 2 MIMO systems, an effective channel emulator should support testing of 4 × 4 MIMO systems in order to allow for hand-off testing between MIMO systems. As an example, the model ACE 400WB channel emulator from Azimuth Systems is a bidirectional unit capable of exercising 4 × 4 MIMO systems. ■

ENSURE RFID SUCCESS WITH PRE-COMPLIANCE TESTING

Radio frequency identification (RFID) applications are expanding rapidly. The promise of accurate and cost-effective asset tracking, secure point-of-sale transactions and supply chain management all contribute to this growth along with US Department of Defense mandates. The adoption of RFID technology is also leading to an increase in available RFID systems and the associated need for pre-compliance and compliance testing.

For the designer, pre-compliance testing can greatly reduce the risk of test failure during compliance verification and the resulting time-to-market problems. However, pre-compliance testing has traditionally been a time-consuming manual process. By gaining an understanding of RFID pre-compliance tests and techniques for automating many test procedures, pre-compliance testing can become practical during a rapid product development cycle.

THE CASE FOR PRE-COMPLIANCE TESTING

In order to display the certification trademark that indicates performance compatibility, most industry standards require successful completion of a battery of compliance tests. These certifications are important to prospective customers since they provide independent assurance that the RFID system will function correctly with a variety of readers and tags from different suppliers.

Compliance testing is similar to any impartial, objective test. Come prepared and it can be an exciting and rewarding experience. Come ill-prepared and it can represent a significant setback. In the fast moving RFID industry, a major cost of being poorly prepared for compliance certification is often the opportunity cost of missing market windows. Failing a compliance certification test and having to reschedule another test can mean weeks of lost revenue from a late product introduction or missing the design socket of an important customer.

The only way to prevent these unpleasant scenarios and pass the compliance test first time out is with intense preparation throughout the design cycle and upfront testing. By committing

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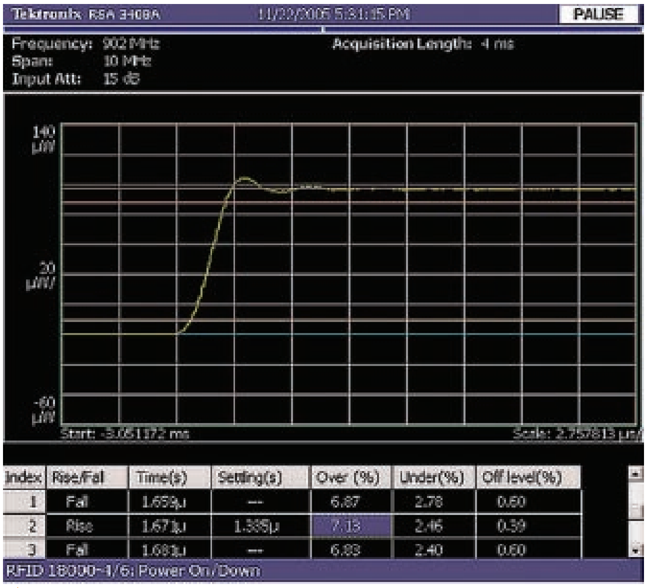

Fig. 1 Pre-compliance measurements like settling time can help ensure interrogators pass compliance testing the first time.

to pre-compliance testing, companies position themselves for a quick pass on the first try and accelerated time to market. It is much less costly to discover a problem before a design leaves the company, then to discover a problem at the compliance certification laboratory. With efficient pre-compliance testing (see ***Figure 1***), a few extra days can save weeks of lost revenue.

Certified test laboratories use custom automatic testing systems to conduct compliance testing. These tests are more exhaustive than the typical bench development testing and often simulate real-world conditions that are hard to replicate in the lab. The time required for most engineers to exhaustively test their designs may not make sense if the measurements are arduously slow to make. The right combination of test equipment and software tools make pre-compliance testing a realistic option.

RFID TESTING CHALLENGES

Technical challenges for developers of RFID test systems encompass both the RF and protocol characteristic of RFID technology. In RFID communication there are high-level signals (in terms of power) transmitted by the readers and low-level back-scattered signals coming from the tags. One of the big challenges is to trigger and capture both types of signals at the same time within microseconds. Testing all the protocol requirements of RFID devices hinges on the ability to generate different types of modulated signals, protocol commands and responses.

For RFID interrogators, typical RF measurements required are frequency accuracy, RF envelope and power-up/power-down waveforms, while for protocol testing it is necessary to verify link timing parameters. For testing RFID tags, the engineer must simulate the interrogator commands for communicating with a given tag. Examples of RF measurements required here are demodulation capability, duty cycle and operating frequency range. On the protocol side, among other requirements, link timing and tag states and transitions have to be checked.

Swept tuned spectrum analyzers, vector signal analyzers and oscilloscopes have traditionally been used for wireless data link development. For RFID product development, however, inherent limitations of these instruments begin to surface. The spectrum analyzer has been used to characterize the RF spectral output of a transmitter to ensure compliance with regulatory emission restrictions. But the traditional swept tuned spectrum analyzer was developed primarily for the analysis of continuous signals not the intermittent RF pulses associated with modern RFID products. This can lead to a variety of measurement issues, particularly the accurate capture and characterization of pulsed RF signals.

The vector signal analyzer also possesses little ability to capture transient RF signals since it was initially developed for continuous wave (CW) signals. Accurate triggering must be coupled with data acquisition to make sure the desired waveform is captured with the limited memory of most vector signal analyzers. Though most vector signal analyzers have extensive demodulation capability for popular spectrally efficient modulations, current offerings have virtually nothing to support the spectrally inefficient RFID modulations and their special Pulse Code Modulation (PCM) decoding requirements. This makes the current generation of vector signal analyzers of little value to the RFID engineer.

The oscilloscope has long been a valuable tool for analysis of baseband signals. In recent years some oscilloscopes have extended their sampling speed to very high microwave frequencies. They are, however, still sub-optimal tools for UHF or higher frequency measurements on RFID systems. Relative to the modern real-time spectrum analyzer, the fast oscilloscope has less measurement dynamic range and lacks modulation and decoding capability.

PRE-COMPLIANCE TESTING SOLUTIONS

The real-time spectrum analyzer (RSA) solves the limitations of the traditional measurement tools by providing an efficient test and diagnostic tool when coupled with RFID measurement software that allows rapid characterization of the many critical industry specification requirements. This combination provides the speed and repeatability to make pre-compliance testing feasible even under the most pressure-filled design conditions.

Pulsed tag reads and writes require an RF analyzer optimized for transient signals. Modern RSAs excel at characterizing transient signals through the use of a real-time architecture and time-correlated displays. The RSA has the digital processing speed necessary to transform input signal from time domain samples into the frequency domain with a real-time Fast Fourier Transform (FFT) prior to capturing a recording of data. Time-correlated analysis in multiple domains greatly enhances the diagnostic insight and reliability by pinpointing the anomaly responsible for an event showing correlated behavior in the different displays of time, frequency and modulation versus time.

RSAs include a built-in tabular data display that enables the engineer to search for compliance issues quickly. With traditional test equipment the labor required to make many of the measurements is so great that only a few spot checks are logistically possible. The high speed at which the RSA

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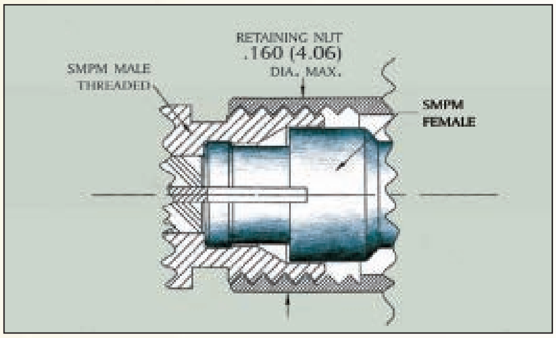

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can take measurements allows the engineer to approximate the exhaustive compliance test much more closely.

Most of the important RF measurements are easily set up and accomplished using RFID measurement software, allowing the engineer to quickly check and recheck compliance with specifications. This reduces the possibility of a surprise failure during the actual compliance test. For example, careful pre-compliance measurement under a variety of conditions testing the interrogator's data burst power-on, power-down and RF envelope ripple can help avoid issues during certification.

If an issue does arise during the compliance test, one approach is to use a transportable RSA to quickly troubleshoot circuits on location. Once a compliance failure condition is known, multi-domain time correlated analysis capability can give the insight needed to trace a failure to its root cause. This can help engineers rescue compliance efforts by rapidly identifying issues.

SPECTRAL EMISSIONS PRE-COMPLIANCE TESTING

To show how a RSA with RFID analysis software can be used for pre-compliance purposes, consider an example such as the key measurements necessary to characterize spectral emissions for government regulatory compliance. Government regulations require that transmitted signals be controlled in power, frequency and bandwidth. The intention is to minimize interference and ensure each transmitter is a spectrally good neighbor to other users of the band.

Power measurements of pulsed signals can be challenging for many spectrum analyzers. In contrast, the RSA is able to optimize transient signals to identify power in a pulsed RFID packet transmission, and FFT analysis presents a complete spectral frame for any given period of time during the packet transmission. This capability eliminates the need to synchronize tuning sweeps with packet bursts—an issue older swept tuned spectrum analyzers had. Also, traditional spectrum analyzers use correction factors to compensate for Successive Log Video Amplifier (SLVA) peak detection circuits. A modern RSA, on the other hand, uses a true RMS detection approach that accurately reads power for most regulatory measurements.

The carrier frequency of the signal is another important spectral emission measurement. There are two ways this measurement can be expressed: actual absolute carrier frequency or carrier frequency error from a given assigned channel frequency. The RSA first displays carrier frequency error when demodulating a signal while the absolute carrier frequency can be displayed in spectrum analysis mode. It's worth noting that demodulated carrier frequency measurement doesn't require the signal to be positioned at the center of the span. This is useful for working with frequency hopping signals.

Other measurements include Occupied Bandwidth (OBW) measurements and Emission Bandwidth (EBW). These can be obtained in two ways. In the demodulation mode the RSA displays the OBW and EBW as well as the carrier frequency and transmission power levels. When these are preprogrammed as automatic measurements, engineers can quickly and accurately determine if their designs meet regulatory requirements (see ***Figure 2***). This eliminates the drudgery of attempting to coax a traditional spectrum analyzer into making measurements on a pulsed RFID signal.

MEETING INDUSTRY STANDARDS

Reliable interrogator and tag interaction requires that designs conform to industry standards such as the ISO 18000-6 Type C specifications. This adds many tests beyond those needed to meet government spectral emissions requirements. RF conformance tests ensure reliable interoperability among tags and readers.

The combination of the RSA and RFID software makes the task of ensuring interoperability much easier. A complete RFID software package contains measurements needed for a broad range of standards such as ISO 18000-4 Mode 1 and ISO 18000-6 Type A, B and C. Preprogrammed

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measurements eliminate most of the setup time required to check out these signal formats. A sampling is shown in ***Table 1***.

For example, one important measurement for ISO 18000-6 Type C is the power-on and power-down time. The rise time of carrier energy must be turned on promptly to ensure the tag collects enough energy to function properly. The signal must also settle out to a stable level. At the end of the transmission, the fall time of the signal burst must be quick enough to avoid disrupting other transmissions. Once the RSA is configured for the test, it will automatically measure power on rise time, power off fall time, power settling time, overshoot and undershoot (see ***Figure 3***). By also displaying the waveform characteristics in a measurement window, the instrument gives the engineer a more detailed perspective for further analysis and debugging.

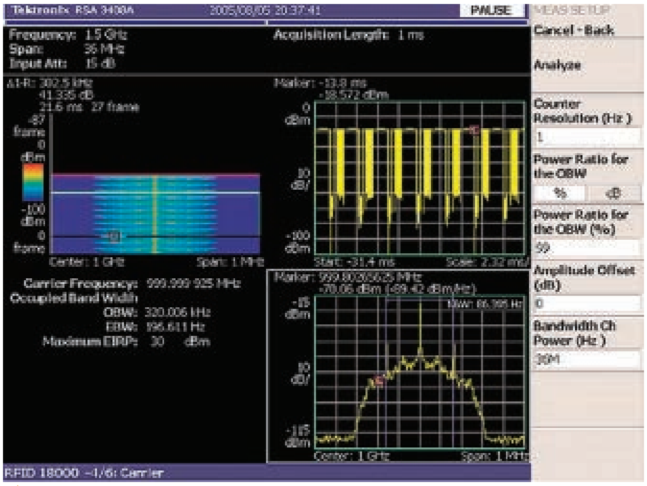

Fig. 2 Key regulatory spectral measurements can be quickly made by displaying the spectrum and choosing the OBW/EBW measurements.

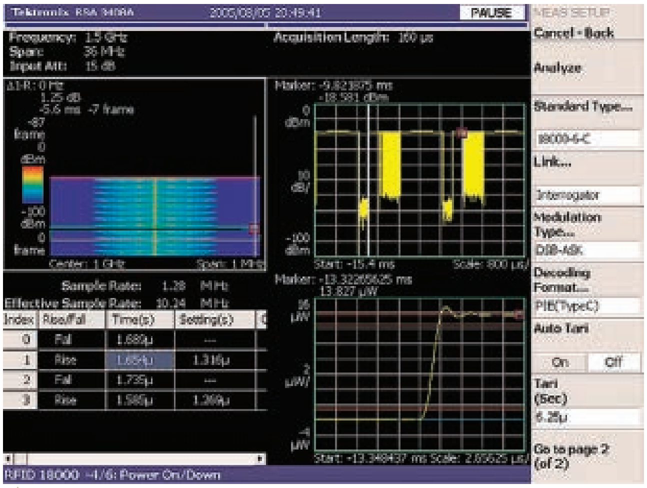

Fig. 3 Power-on and power-down measurements for query session can be tested using automated RFID software on the RSA.

Communications between interrogator and tag are accomplished with ASK signal bursts during the power-on period. These signal bursts make up the RF envelope and are important for interoperability. The modulation pulse envelope contains characteristics necessary to assure compatibility between reader and tag. Here, the RFID software can be tapped to automatically measures RF envelope specifications like on width, off width, duty cycle, on ripple, off ripple and the slopes of the RF envelope edges.

Another application is to characterize a variety of modulation envelopes including DSB-ASK, SSB-ASK and PR ASK using the RSA. To simplify keeping track of protocol transmissions, it is useful to have RFID software that first labels individual bursts with an index number and then further subdivides bursts into envelope numbers that show individual symbol parameters.

Once the basic specifications are met and you are sure of obtaining certifications, it is important to optimize some of the RFID product's features to gain a competitive advantage in a particular market segment. A modern test environment can be extremely valuable in maximizing system performance while at the same time minimizing the engineering commitment necessary to achieve desired goals.

CONCLUSION

The RFID industry encompasses a broad array of technologies and applications, many of which differ from

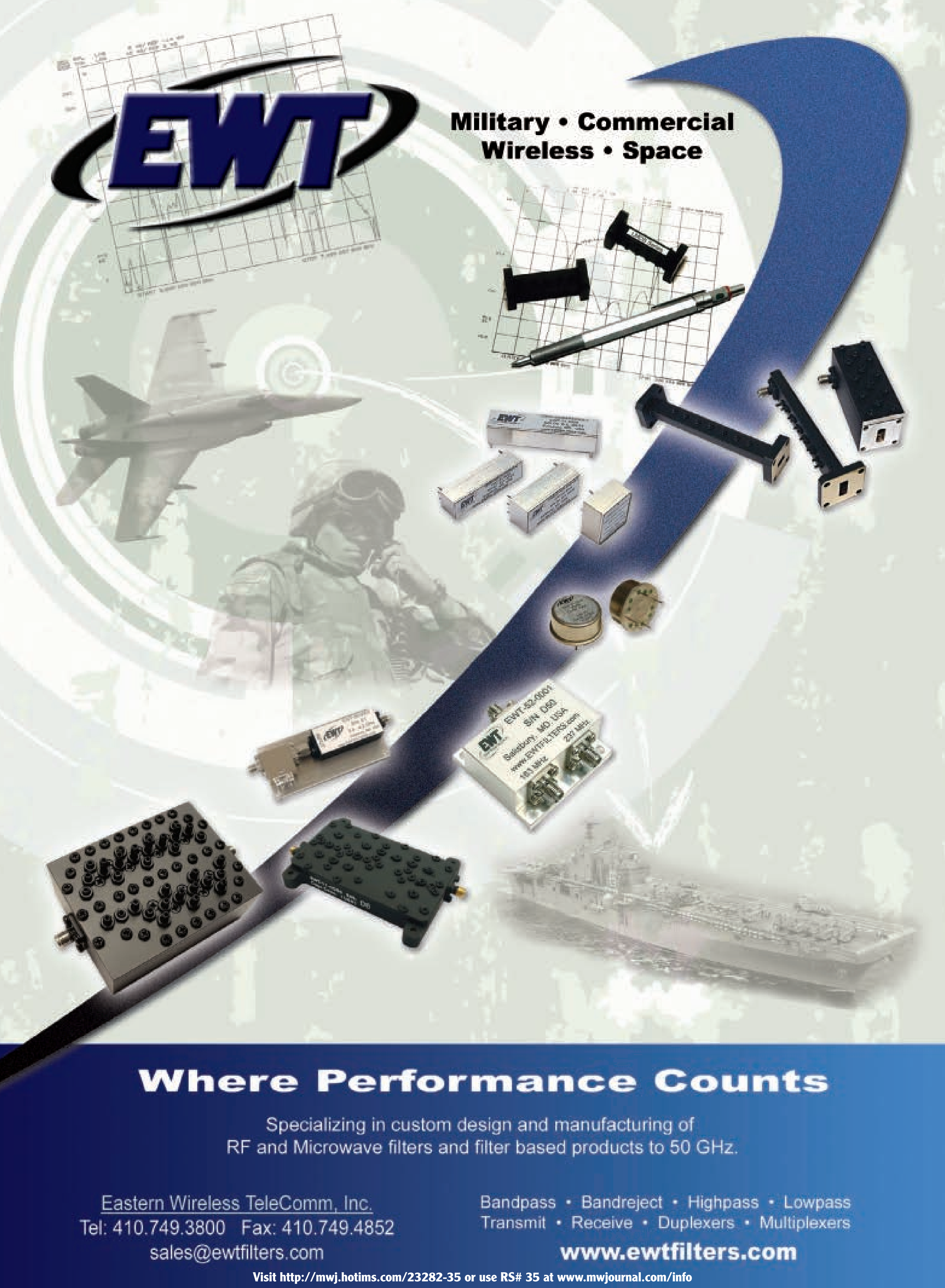
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TABLE I

PRESET MEASUREMENTS GREATLY REDUCE SETUP TIME WHEN CHECKING COMPLIANCE WITH STANDARDS

Menu	Measurement	Standard					
		ISO 18000-4 Mode 1	ISO 18000-6 Type A, B & C	ISO 14443-2 Type A & B	ISO 18092 (424 k)	ISO 15693-2	ISO 18000-7
Carrier	Carrier Frequency	■	■	■	■	■	■
	OBW/EBW	■	■	■	■	■	■
	Avg. Power for Pwr. On	■	■	■	■	■	■
Spurious	Spurious	■	■	■	■	■	■
ACPR	ACPR	■	■	■	■	■	■
Power On/ Down	Transmission Power	■	■	■	■	■	■
	Rise & Fall Time	■	■	■	■	■	■
	Settling Time	■	■	■	■	■	■
	Over/Under Shoot	■	■	■	■	■	■
	Off Level	■	■	■	■	■	■
RF Envelope	On/Off Width	■	■	■	■	■	
	Duty Cycle (%)	■	■	■	■	■	
	On/Off Ripple	■	■	■	■	■	
	Rise Time	■	■	■	■	■	
	Fall Time		■	■	■	■	
FSK Pulse	On/Off Width						■
	Period/Duty						■
	On/Off Ripple						■
	Slope 1, 2, 3						■
Constellation	Modulation Depth	■	■	■	■	■	■
Eye Diagram	Modulation Index	■	■	■	■	■	■
Symbol Table	Frequency Error	■	■	■	■	■	■
	Bit Rate (Measured)	■	■	■	■	■	■
	Tari Length (0 & 1)	■	■	■	■	■	■
	Indicated Preamble	■	■	■	■	■	■
Marker	Turn Around Time	■	■	■	■	■	■

the typical communications link. For example, the latest international RFID standards call for sophisticated frequency-hopping spread spectrum (FHSS) signals with transient half duplex RF bursts composed of ASK modulations with unusual encoding and robust anti-collision protocols. Given the rapid pace of change, the level of complexity involved and the rigor of certification testing, designers can no longer take the risk of going to certification labs without having first performed pre-compliance testing.

The modern RSA combined with a comprehensive RFID analysis software package that includes international RFID standards support greatly speeds development diagnostics and provides a feasible way of conducting pre-compliance testing. The RSA also helps engineers perform RFID measurements that either cannot be made or would require elaborate, time-consuming test setups on traditional swept spectrum analyzers or vector signal analyzers. ■

Darren McCarthy *earned his BSEE degree from Northwestern University in Evanston, IL. He is currently technical marketing manager for RF Test at Tektronix. He has worked extensively in various test and measurement positions for the last 18 years, including R&D engineer, R&D management, product planning and business development. During his career, he has also represented the US on several IEC technical committees for international EMC standards.*

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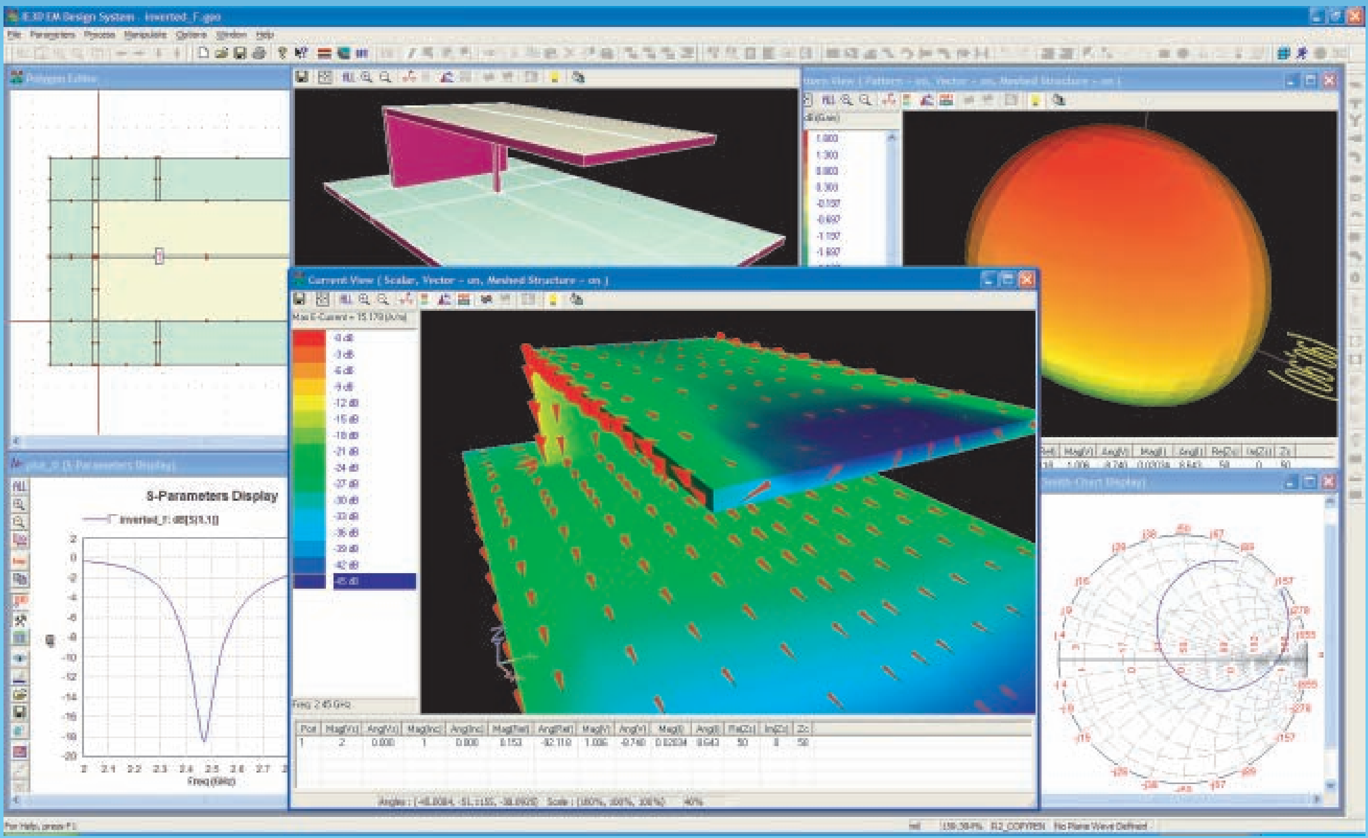

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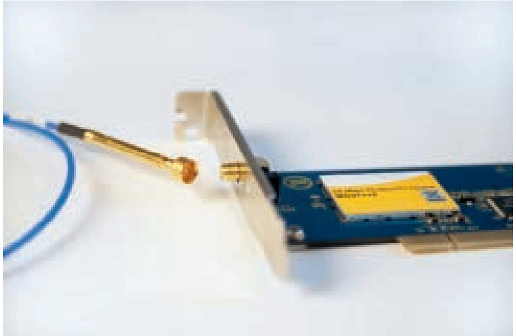


NEXT GENERATION RF TEST PROBES

Accurate and efficient probing techniques play a vital role in the production process in order to guarantee the functionality for the customer. This is particularly true for today's high speed, high data rate and wireless-everywhere generation where it is crucial to provide the industry with high performance testing solutions. That is precisely the market that INGUN has addressed when developing the HFS RF test probe series.

As a global specialist in the test and measurement business, the company has developed the series to complement its extensive range of highly precise mechanical products that constitutes the world's largest selection of both general probes and spring-loaded RF probes as well as a wide variety of test fixtures. In the portfolio there are 10,000 general probe varieties and 475 different varieties of spring-loaded RF probes for either contacting a coaxial interface or directly contacting a pad on the surface of a PCB.

APPLICATIONS

The HFS RF test probes have applications in virtually all sectors of the electronics industry, including the testing of automotive equipment (car stereos and GPS systems), telecommunications (cell phones), WiFi, ZigBee and UWB to name just a few. They feature a modular design approach where the probe body always stays the same (with regards to mechanical dimensions) and only the screw-in head has to be modified to meet the contacting needs of the customer.

▲ *Fig. 1 The HFS 860 201 051 A 5306 S probe for layouts where the ground ring is open on one side.*

In this product feature the focus is on the two latest tip-style additions for the HFS-860 6 GHz series, featuring R-SMA contacting for consumer-WLAN products and 6 GHz PCB pad contacting for contaminated surfaces. HFS-860 products are equipped with snap-in MCX input interfaces, which allows a secure and easy connection of a coaxial feed cable (e.g. SE-860-V-80 assembly or customer cable).

The two tip-style additions are the HFS 860 201 051 A 5306 S and the HFS 860 303 150 A 5343 ER. INGUN probes have an intelligent part number system, which is informative and descriptive as it includes spring forces, material, tip style and maximum operating range—all in one number. The whole part number is laser-engraved on the outer barrel to prevent mix-ups.

HFS 860 201 051 A 5306 S

This probe is intended to be used for layouts where the ground ring is open on one side (see ***Figure 1***). The ground ring is serrated, which means that the outer connector facilitates a secure ground connection even on highly contaminated boards. Another advantage of the serrated design is that it is much easier to penetrate through layers of flux and dust than is the case for a flattened style. For clean environments the usage of a flat outer-conductor design is recommended (e.g. the HFS 860 201 051 A 5302).

HFS 860 303 150 A 5343 ER

Whenever WLAN boards with reverse-SMA connectors have to be tested (this is the case for many routers, PCI-WLAN cards, etc.), the HFS 860 303 150 A 5343 ER is the right probe choice. Allowing signal transmission up to 6 GHz, this probe covers both the 2.4 and 5.8 GHz bands with ease.

INGUN PRüFMITTELBAU GMBH
Konstanz, Germany

MEASUREMENT RESULTS

The performance of the RF probes is constantly tested to ensure excellent electrical characteristics. The S-parameters are determined using either manual or semi-automatic test stations and a vector network analyzer. The test setups are calibrated using full-two-port short-open-load-reciprocal (SOLR) calibration. Also, whenever necessary, further steps are taken to compensate for losses through additional adaptors that have been inserted after the calibration has been done (such as contacting interfaces, PCB contacting pads, etc.).

Table 1, and ***Figures 2*** and ***3*** show the typical S-parameter values of the probes. For the probe itself, the matching can be kept well above 15 dB/20 dB within the specified frequency range. Of course, the performance is highly dependent on the method of contact and the PCB pad or coaxial interface to-be-contacted. INGUN recommends using a complete testing solution consisting of fixture + probe to ensure good contact.

However, a probe without a good cable connection to the test system or interface is worthless. Users should not just select the test probe without considering the cable assembly it is to be used with, whether pre-configured or customized. For instance, the HFS RF test probes are highly compatible with the standard SE-860 series cable, which exhibits very low insertion loss and good impedance stability. ***Figure 4*** shows the performance of SE-860 cable assemblies, which can easily be used in conjunction with the HFS RF test probes. The values are given for a cable length of 80 cm; losses for other lengths can be approximated using the formula:

$$\alpha\left[\mathrm{dB}\right] \approx (0.77270\sqrt{f} + 0.09720f)l$$

TABLE I

ELECTRICAL CHARACTERISTICS (TYPICAL VALUES)

		HFS 860 201 051 A 5306 S	HFS 860 303 150 A 5343 ER
Nominal impedance	Z_o	50 Ω	50 Ω
Return loss[1]	S_{11}	≥20 dB @ 1 GHz ≥15 dB @ 6 GHz	≥20 dB @ 2.4 GHz[2] ≥15 dB @ 5.8 GHz[2]
Insertion loss[1]	S_{21}	0.09 dB @ 1 GHz 0.67 dB @ 6 GHz	0.14 dB @ 1 GHz 0.60 dB @ 6 GHz
Max. operating frequency	f	6 GHz	6 GHz
Velocity of propagation	v	$\approx 0.93 \cdot c_0$	$\approx 0.94 \cdot c_0$
Signal delay	τ	138 ps	144 ps
Phase	φ	50° @ 1 GHz 302° @ 6 GHz	51° @ 1 GHz 307° @ 6 GHz
Capacitance	C'	71.7 pF/m	70.9 pF/m
Inductance	L'	0.179 μH/m	0.177 μH/m

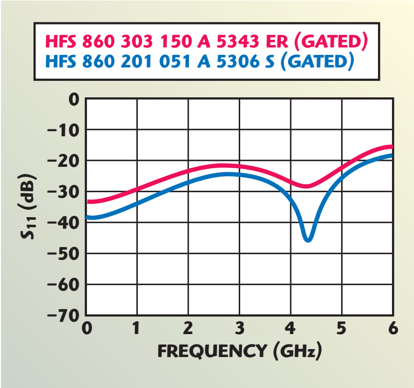
[1]Values are given for the probe only (not a complete assembly)
[2]Return loss values are given for the most common frequencies of interest (WLAN applications)

THE FUTURE

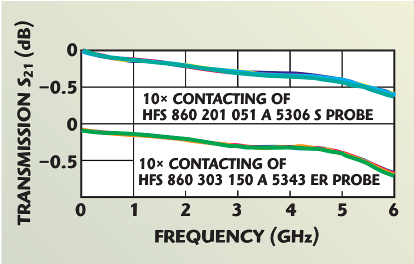
Engineers are currently working on a new probe solution for applications ranging up to 12 GHz and higher (the HFS-865 series); thus, not only will UWB signals be covered but virtually any high speed data applications up to the specified frequency. This model features an improved body design with MMPX™-input interface and is a joint venture between INGUN and Huber + Suhner.

CONCLUSION

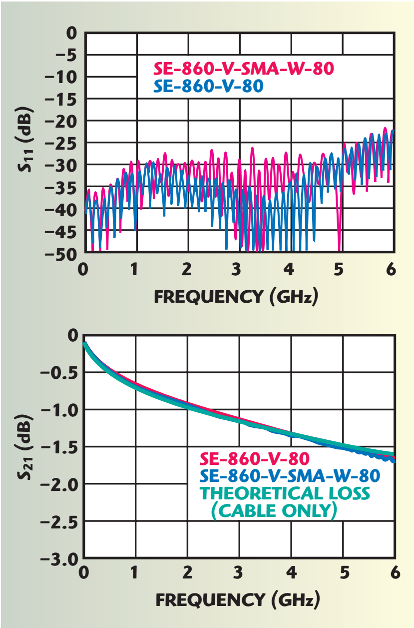
The HFS RF test probe series is an easily configurable yet highly precise way for contacting PC boards and interfaces. Because they are spring-loaded probes there is no need to screw-in/plug-in some interfaces, with the result that time can be saved when carrying out high-volume pass/fail tests. With the latest tip-styles for the HFS-860 series and the upcoming HFS-865 probe, virtually all applications can be covered. For those that are not, the modular design approach allows customer-specified solutions to be developed quickly.



▲ *Fig. 2 Typical return loss of probes.*



▲ *Fig. 3 Typical insertion loss of probes.*



▲ *Fig. 4 Performance of SE-860 cable assemblies.*

INGUN Prüfmittelbau GmbH, Konstanz, Germany
Tel: +49 7531 8105-0,
e-mail: rf@ingun.com.
www.ingun.com

RS No. 301

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IF/RF MICROWAVE COMPONENTS

457 rev D

NEW DIGITAL ATTENUATOR PRODUCT LINE

EXECUTIVE INTERVIEW SERIES

MWJ SPEAKS WITH FRANK WODOSLAWSKY, PRESIDENT AND CEO, WEINSCHEL ASSOCIATES.

VISIT WWW.MWJOURNAL.COM TO READ THIS IN-DEPTH INTERVIEW.

The Weinschel Associates DA series of digital attenuators represents the latest in programmable attenuator technology. The DA attenuator architecture combines the rugged design and superior performance expected of Weinschel Associates products with modern technology to achieve the ease of integration and price performance expected in a plug-and-play marketplace. The DA family of attenuators is targeted toward a multitude of commercial and military applications, including test instrumentation, base station infrastructure, broadband telecommunications, microwave and VSAT radios, and radar systems.

The DA product line is structured to offer broadband frequency coverage (DC to 6 GHz and DC to 13 GHz versions), in a selection of attenuation ranges (30, 60 and 90 dB), all with a 0.5 dB step size. The attenuators feature the high accuracy, repeatability, and fast switching speeds (< 100 ns) of a digital solution as well as a power rating of 0.3 W CW (+25 dBm) to enable their integration into a broad spectrum of applications. ***Tables 1*** and ***2*** delineate the current offerings in the DA product family along with the insertion loss for each model versus frequency. Rounding out the performance features of the DA product line are a +22 dBm 0.1 dB compression point, a +32 dBm third-order intercept point and a maximum phase shift with change in attenuation of 1 degree per dB x f (GHz).

Ease of use has been addressed through the implementation of a standard USB 2.0 interface and the inclusion of a user friendly software application and device driver. The unit draws its power from the USB interface eliminating the need for an external power source. The DA Controller software (see ***Figure 1***) searches out available serial (COM) ports on the host computer and presents those in a drop down list. The provided device driver recognizes when a DA series attenuator is installed

WEINSCHEL ASSOCIATES
Gaithersburg, MD

TABLE I
DA PRODUCT FAMILY WITH INSERTION LOSS VALUES

Model	Frequency Range (GHz)	Attenuation Range (dB)
DA6-30	DC - 6	30
DA6-60	DC - 6	60
DA6-90	DC - 6	90
DA13-30	DC - 13	30
DA13-60	DC - 13	60
DA13-90	DC - 13	90

TABLE II
DA PRODUCT FAMILY WITH INSERTION LOSS VALUES

Model	Insertion Loss (dB, max) vs Frequency		
	DC to 4 GHz	4 to 6 GHz	6 to 13 GHz
DA6-30	3	4	NA
DA6-60	7	9	NA
DA6-90	11	13	NA
DA13-30	4	5	6
DA13-60	8	10	12
DA13-90	12	15	18

▲ *Fig. 1 Digital attenuator control widget.*

on a USB port and creates a virtual COM port that will appear on the list. Once the port is selected, the slider and/or increment/decrement box may be used to control the DA directly.

If the user prefers to integrate the control of the DA into a National Instruments (NI) LabView application or a proprietary application, WA will provide a library (dll) file for inclusion. Custom software solutions and support are also available.

Again, the objective of the Digital Attenuator User Interface is simplicity. The DA product line effectively eliminates the need for expensive and complicated hardware and software interfaces, allowing the user to easily and cost-effectively implement the programmable attenuator function in their RF chain.

Weinschel Associates,
Gaithersburg, MD (301) 963-4630,
www.weinschelassociates.com.

RS No. 300

Test Solutions

Aeroflex.com has been completely redesigned to be more user-friendly and easily accessible. The new site utilizes several convenient new features including a streamlined corporate home page and Aeroflex Test Solutions page, a product locator feature that makes finding products a snap and an integrated Google™ search engine.

Aeroflex, 35 South Service Road, PO Box 6022, Plainview, NY 11803-0622

www.aeroflex.com

Multimedia Resource

VendorView

AWR announced that its new web site, www.awr.tv, is now "live", providing a wealth of multimedia content targeted to the company's broad base of users as well as potential customers interested in learning more about AWR high-frequency EDA tools including Microwave Office®, Analog Office®, Visual System Simulator™ (VSS), APLAC™ and AXIEM™ software. AWR has tailored AWR TV to be a comprehensive "one-stop" resource for product information, tutorial presentations and application-specific discussions.

AWR, 1960 E. Grand Avenue, Suite 430, El Segundo, CA 90245

www.awr.tv

Advanced Capacitors

This web site shares technical information, white papers, specs and pricing for the company's energy-dense Hybrid® capacitors and Hybrid capacitor banks. High performance aircraft, including the Joint Strike Fighter and the Apache helicopter, use Evans Hybrid Capacitors for laser targeting, communications modules, controls, cockpit displays, phased-array radars and fire control systems. Evans tantalum, hermetic, Hybrid capacitors have over 4× the energy density of any military-style capacitor.

Evans Capacitor Co., 72 Boyd Avenue, East Providence, RI 02914

www.evanscap.com

ICs, Modules and Subsystems

VendorView

Hittite's redesigned web site includes crisp new webpage designs and a dynamic homepage featuring full specifications for 700 products across 18 product lines, press releases and featured articles. Comprehensive Individual Product "Splash Pages" containing in-depth product information and technical content are located on one easy to navigate page. Engineers will find improved Product Support and streamlined Quality & Reliability pages containing invaluable reference materials.

Hittite Microwave Corp., 20 Alpha Road, Chelmsford, MA 01824

www.hittite.com

High Frequency Ceramic Solutions

Johanson Technology provides High Frequency Ceramic Solutions for cellular, WLAN, Bluetooth, RF/microwave, millimeter-wave, and fiber optic applications, as well as custom high frequency ceramic solutions. The company offers a broad range of multi and single layer capacitors, RF inductors, LTCC-based chip antennas, baluns, balanced filters, band pass filters, low pass filters, couplers, and diplexers, as well as other components.

Johanson Technology, 4001 Calle Tecate, Camarillo, CA 93012

www.johansontechnology.com

Filtering Solutions

K&L Microwave's redesigned web site features improved product navigation and an integrated quote cart that enhances the customer's ability to review available products, simplify identification and specification of custom design solutions, and speed direct communication with the factory. Also, the new product catalog is available to download. The entire catalog or specific sections of interest can be downloaded by using provided links.

K&L Microwave, 2250 Northwood Drive, Salisbury, MD 21801

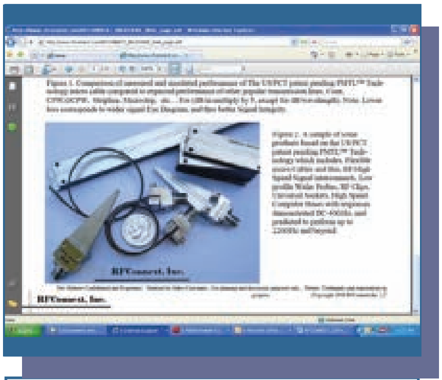
www.klmicrowave.com
www.klfilterwizard.com

Interactive Product Catalog

This web site provides a comprehensive, user-friendly selection of Empower's products and functionality to configure and submit quote requests. The site features a parametric search engine and a collection of RF engineer's applets such as a watts-to-dBm converter, gain calculator and links to contact Empower's sales team. There is also a mobile-friendly version accessible from devices such as a RIM Blackberry.

Empower RF Systems Inc., 316 West Florence Avenue, Inglewood, CA 90301

www.empowerrf.com



Interconnect Technology

RFConnext Inc. has a new webpage featuring its products and services. The company has developed PMTL™, a new patent pending, transmission line technology, for high speed interconnect and packaging of devices and systems. This webpage provides datasheets for a family of products, based on the patent pending PMTL, such as single and differential impedance flex/rigid jumper/connectors, wafer and PCB probes, test fixtures and sockets, and technical service targeting the signal integrity, and testing connectivity market, across the spectrum.

RFConnext Inc., info@rfconnext.com, (408) 981-3700

www.rfconnext.com

Frequency Control, Sensor and Hybrid Product Solutions

Vectron International is a leader in the design, manufacture and marketing of frequency control, sensor and hybrid product solutions. Vectron solves complex timing, filtering and sensor challenges by delivering customized solutions that speed time to market and offer low total cost of ownership. Vectron uses the very latest techniques in both bulk acoustic wave (BAW) and surface acoustic wave (SAW)-based designs from DC to microwave frequencies.

Vectron International, 267 Lowell Road, Hudson, NH 03051

www.vectron.com

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LTE Receiver Measurements

VENDORVIEW

Agilent announces LTE Receiver Measurements as a software upgrade to its proven drive test platform, protecting customers' previous investments in receiver hardware and offering multiple tests that accelerate deployment of LTE networks. Network equipment manufacturers and wireless service providers can use the software on Agilent receivers to quickly verify base station RF coverage, plot accurate coverage maps and validate planning, all of which speeds the deployment of LTE networks. The Agilent platform offers the most practical and least costly option for initial field testing, and reduces the need for a large number of far more expensive "rack-and-stack" test phones.

Agilent Technologies Inc., Santa Clara, CA (800) 829-4444, www.agilent.com.

RS No. 243

Microwave VNA

VENDORVIEW

The VectorStar^{TM} MS4640A microwave VNA delivers best-in-class frequency coverage of 70 kHz to 70 GHz, dynamic range of 103 dB at 67 GHz, and measurement speed of 20 µs/point to establish a new performance benchmark for S-parameter measurements on RF, microwave and millimeter-wave devices. The VectorStar MS4640A family offers three standard frequency ranges that go to 20, 40 and 70 GHz. This high performance two-port engine is designed to add future capabilities, and is compatible with existing four-port and broadband mmW systems for 70 kHz to 110 GHz measurements, or waveguide banded measurements up to 500 GHz. VectorStar brings unprecedented performance to traditional VNA markets, including aerospace/defense, satellite, commercial microwave communications, materials measurement and advanced research.

Anritsu Co., Morgan Hill, CA (800) 267-4878, www.anritsu.com.

RS No. 216

Spatial Channel Modeling Tool

EB announced the availability of its Spatial Channel Modeling Tool for its EB Propsim radio channel emulators for Mobile WiMAX and 3GPP LTE. The Spatial Channel Modeling Tool supports both the use of SCM and SCME channel models and is ideal for testing a range of applications including mobile devices and base stations. The Tool is based on a geometry-based stochastic modeling method for system-level emulations between multiple base stations and multiple mobile stations. Performance metrics such as throughput and delay are measured over a large number of emulation runs, called "drops", which consist of a predefined number of radio frames. During a drop, the channel experiences fast fading according to the movement of the terminals.

Elektrobit Corp. (EB), Oulu, Finland +358 40 344 2000, www.elektrobit.com.

RS No. 244

VNA Frequency Extension Products

These VNA Frequency Extension products can be used with the Agilent PNA, Anritsu VNA or Rohde & Schwarz ZVA to extend the frequency range capabilities. They cover four frequency bands, from 40 up to 110 GHz, with ongoing development to extend that range to 325 GHz and beyond. The products in the range include the controller box that is used for signal routing, switching and amplification. It communicates with the analyzer providing fully automatic two-port S-parameter measurement and also provides power to the extender heads. The frequency extension head configuration can either be a transmission and or a transmission/reflection unit. It is thus possible to do either a full two-port S-parameter measurement using two T/R heads or only S21 and S11 using the T/R and T configuration.

Farran Technology Ltd., Ballincollig, Co. Cork, Ireland +353 21 487 2814, www.farran.com.

RS No. 218

Calibrated Noise Source

The NW346 series is a broadband calibrated noise source available in standard output levels 6, 15 and 25 dB ENR. These units are designed for noise figure test and are compatible with standard noise figure meters as well as spectrum analyzers and networks analyzers. They are supplied in industry standard packaging and are economically priced with delivery typically from stock.

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

RS No. 219

Portable Signal Generator

LMPL_SG_2000 is a portable signal generator that operates in a frequency range from 1 to 2 GHz. It features a Divide-by-Two auxiliary output, is PC-controlled with user-friendly software, offers eight programmable manually-operated frequencies, programmable amplitude control, output disable, internal or external reference with automatic detection, visual indicator for lock detect, hand-sized rugged metal housing and an AC adapter. Size: 6.5" × 4.3" × 1.2".

General Electronic Devices, San Marcos, CA (760) 591-4170, www.gedlm.com.

RS No. 217

Portable Passive Intermodulation Analyzer

VENDORVIEW

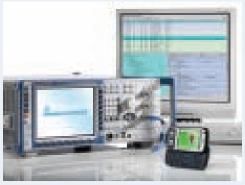
This portable PIA enables quick and accurate measurements of the intermodulation characteristics of passive components, e.g. connectors, cable assemblies, antennas, filters and other passive components. Packaged in a shock-proof case the analyzer can be used for the precise analysis of the RF infrastructure quality and performance of radio base stations as well as for laboratory and manufacturing applications. The portable PIAs are available for the following frequency bands: AMPS, EGSM, DCS, PCS, UMTS, UMTS II/LTE and WiMAX.

Rosenberger Hochfrequenztechnik GmbH & Co. KG, Fridolfing, Germany +49 08684 18-263, www.rosenberger.de.

RS No. 220

Flexible Multi-standard Test Platform

VENDORVIEW



The R&S CMW500 wideband radio communication tester supports wireless devices through all stages of development and production. When equipped with the appropriate hardware and software components it can perform T&M tasks ranging from RF and protocol tests up to complex application tests. It handles everything from the first steps in developing a wireless device up to the final conformance test. The R&S CMW500 features a frequency range up to 6 GHz and its modular concept enables users to add new standards with optional software updates, yielding minimum test costs and maximum flexibility. It supports the following standards by means of specific feature sets: GSM/(E)GPRS, WCDMA/HSPA, UMTS LTE, TD-SCDMA, CDMA2000® 1xRTT, CDMA2000® 1xEV-DO, Mobile WiMAX^{TM}, WLAN, Bluetooth®, DVB-T and GPS.

Rohde & Schwarz, Munich, Germany +49 89 4129 13774, www.rohde-schwarz.com.

RS No. 245

Components

Transfer Switches

The TA/TD Series features SMA connectors and operates in a frequency range from DC to 18 GHz. The TAE/TDE Series also features SMA connectors and a frequency range of DC to 26.5 GHz. Both series are available with failsafe, latching self cut-off or pulse latching functions. Weight (max): 6 oz.

Ducommun Technologies Inc.,
Carson, CA (310) 513-7214,
www.ducommun.com.

RS No. 246

Bias Tee/Diplexer

VENDORVIEW

Mini-Circuits has developed a new bias tee/diplexer (ZABT-2R15G +) that is well suited for Satellite/VSAT, LNB converter, and BUC and modems. The ZABT-2R15G+ can be used as a bias tee or diplexer that can inject 10 MHz and DC on an L-band signal. It can also be used in the reverse direction, which can strip off the DC and/or 10 MHz signal. A prime application for this model is in a satellite system where the basic architecture consists of a modem usually in the base or hub. This modem will convert IF signals to L-band (950 to 2150 MHz). The L-band will then be moved over a cable to the BUC located usually at the antenna. To minimize the length of cables and the number of cables a bias tee diplexer is used to combine the L-band signal and a separate 10 MHz signal that synchronizes the synthesizer internal to the BUC and the DC to power the BUC.

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

RS No. 229

LNA and Mixer Modules

VENDORVIEW

The HMC-C049 is a GaAs MESFET mixer module that provides 7 dB of conversion loss, 48 dB of LO to RF port isolation and a consistent +20 dBm of input IP3 across the frequency range of 7 to 14 GHz. This passive double-balanced mixer module is carefully designed to ensure a wide IF bandwidth of DC to 5 GHz and can operate with an LO power level of +9 dBm. The HMC-C049 is housed in a hermetically sealed module that is assembled and tested to meet MIL-883-STD. The HMC-C050 is a GaAs HBT ultra low noise amplifier that delivers exceptional phase noise performance of -160 dBc/Hz at 10 kHz offset and is designed to operate over the frequency range of 2 to 18 GHz.

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

RS No. 242

Pseudo Elliptic Bandpass Filter

KR Electronics introduces part number 2881, a surface-mount 440 MHz pseudo elliptic bandpass filter. The filter offers a typical insertion loss of 2.5 dB, a minimum 3 dB bandwidth of 50 MHz and a maximum 60 dB bandwidth of 127 MHz. The use of a pseudo elliptic type filter gives performance not typically attainable with all-pole filter types. The typical 3 dB bandwidth is 70 MHz and the typical 60 dB bandwidth is 120 MHz for a shape factor of 1.72:1. The filter is supplied in a surface-mount package measuring 2.25" × 0.5" × 0.3" and can also be supplied connectorized. The filter can be customized for other center frequencies and bandwidths.

KR Electronics Inc.,
Avenel, NJ (732) 636-1900,
www.krfilters.com.

RS No. 221

30 GHz Coax Isolator

This new high frequency coax isolator is designed for satellite uplinks operating from 27.5 to 30 GHz. The 0.50" × 0.50" × 0.63" package includes two mounting holes with 0.37" spacing. This device maintains 18 dB isolation, less than 0.85 dB insertion loss, and better than 1.40 VSWR over the temperature range of -40° to +65°C. The power ratings are 5 W forward and 0.5 W reverse.

M2 Global Inc.,
San Antonio, TX (210) 561-4800,
www.m2global.com.

RS No. 222

SPDT Switch

VENDORVIEW

The MASW-000825-12770T is a 20 W broadband HMIC™ PIN diode SPDT switch that is designed for WiMAX, LTE and other high linearity/power applications. The compact 3 mm PQFN package of the MASW-000825-12770T offers a small high-power solution. It also offers broadband 50 MHz to 6 GHz operation with excellent isolation to insertion loss ratio for both Tx and Rx states. Specifically, this switch achieves almost 30 dB of Tx to Rx isolation with less than 0.3 dB of associated insertion loss and 64 dBm IIP3 for the 2.3 to 2.7 GHz WiMAX band while reliably handling up to 20 W of CW power.

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

RS No. 223

Attenuators and Loads

VENDORVIEW

These reverse polarity TNC (RP-TNC) attenuators and loads are specifically designed for Wi-Fi and Wireless LAN systems. These attenuators and loads offer 2 W average power (2 kW peak), DC to 3.000 GHz. RP-TNC reverses the polarity of the interface to female contact pins into the male connectors and male contact pins into the female connectors. Stock – two weeks ARO. The products are made in the USA and offer a 36-month warranty.

MECA Electronics Inc.,
Denville, NJ (866) 444-6322,
www.e-meca.com.

RS No. 224

Miniature Ultra-flat Schottky Detectors

VENDORVIEW

RLC Electronics' miniature ultra-flat detectors utilize a zero-bias Schottky design. The microwave power is coupled directly to the extremely small components reducing package parasitics and transition mismatches. This design results in a very low VSWR and a flat, smooth output over a wide bandwidth. Options available include negative or positive output, a choice of three output connectors and operation to 26.5 or 40 GHz.

RLC Electronics Inc.,
Mount Kisco, NY (914) 241-1334,
www.rlcelectronics.com.

RS No. 225

Amplifiers

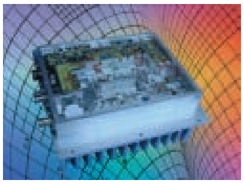
GaN Broadband Power Amplifier

The model SSPA 0.8-2.5-125 is a high power, broadband, Gallium Nitride (GaN) RF amplifier that operates from 800 to 2500 MHz. This PA is ideal for broadband military platforms as well as commercial applications because it is robust and offers high power over a multi-octave bandwidth with decent power added efficiency. This amplifier was designed for high efficiency applications. The unit is displayed with a heat sink and this is offered as option. This amplifier operates with a baseplate temperature of 85°C with no degradation in the MTBF for the GaN devices inside. It is packaged in a modular housing that is approximately 3.4" (width) by 8.3" (long) by 1.3" (height).

Aethercomm Inc.,
Carlsbad, CA (760) 598-4340,
www.aethercomm.com.

RS No. 227

100 W Power Amplifier



Model MSD-2X0X901-GC is a solid-state power amplifier that operates in a frequency range from 1.5 to 1.6 GHz. This PA offers 100 W saturated output power with input power as low as -12 dBm. It has 20 dB of gain control, precision RF power out detector circuitry and temperature compensation. This PA is also available in bandwidth range of 20 percent from 800 MHz to 2.1 GHz with saturated output power up to 150 W.

Microwave Solutions Inc.,
National City, CA (619) 474-7500,
www.microwavesolutions.com.

RS No. 228

Infinite Solutions!

AT6080 Log Periodic Antenna
80 MHz-6 GHz, 5000 Watts Input Power

250A250A
250 Watts CW, 10 kHz-250 MHz

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AS40000 System

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CI00250 & CI00400
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2 W Millimeter-wave Power Amplifier

VENDORVIEW

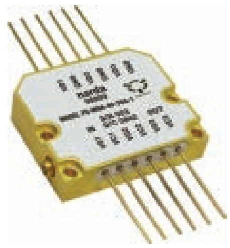
Model AMF-5B-33003500-80-32P is a connectorized high power amplifier/module that operates in a frequency range from 33 to 35 GHz and delivers approximately 2.5 W of saturated power and 2 W of P1dB over a 2 GHz band. The connectorized Aluminum alloy housing is 19 mm high, 76 mm long and 89 mm wide. Connectors are female, K-type. It is intended for bolting to a flat cooling surface. Nominal small-signal gain is over 50 dB. Noise figure is nominally 6 dB. Output VSWR is a maximum of 2.3 and input is 2:1 maximum.

MITEQ Inc.,
Hauppauge, NY (631) 436-7400,
www.miteq.com.

RS No. 230

Modulator Driver

VENDORVIEW

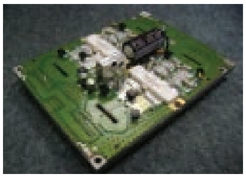


The FO-MDA-40-25G-1 is a low cost, high performance lithium niobate modulator driver that delivers exceptional performance in 300-pin MSA transponders employed in DPSK long-reach 40-Gb/s lightwave communication systems. FO-MDA-40-25G-1 combines monolithic microwave integrated circuits (MMIC) developed by Narda specifically for modulator driver applications along with proprietary fabrication techniques. The result is a three-stage modulator driver that produces an exceptional eye pattern and has a 3 dB bandwidth of 85 kHz to 40 GHz, gain of 29 dB, input and output return loss of 12 dB, RMS additive jitter of only 550 ps, rise and fall times (20 to 80 percent) of 10 ps, and output power up to 8 Vpp with an input voltage of 450 mVpp. Size: 1.1" × 1.1" × 0.34".

Narda Microwave-East,
Hauppauge, NY (631) 231-1700,
www.nardamicrowave.com/east.

RS No. 231

Broadcast Pallet Amplifier

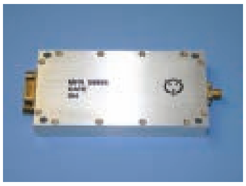


The RES-INGENIUM (Orvieto, Italy) LDU671C is a high-linearity pallet amplifier designed specifically for HDTV television broadcasters. It features the powerful MRF6VP3450H LDMOS transistor from Freescale™ Semiconductor. This Class AB amplifier will typically deliver a robust 150 W average HDTV power (more than 650 W PEP), with 40 percent drain efficiency and shoulders (±4.2 MHz) at -32 dBc. The combination of high-efficiency, high-linearity, ample gain and reduced physical size allows the broadcaster to reduce annual energy consumption, decrease overall transmitter costs and increase reliability. Gain flatness is typically ±0.75 dB.

Richardson Electronics,
LaFox, IL
(800) 737-6937,
www.rfwireless.rell.com/amplifiers.asp.

RS No. 232

RF Driver



This custom RF driver is designed to control an Acousto-Optical Q-switch for IRCM applications. The RF driver generates a crystal stabilized signal in the UHF band, and features a voltage controllable output of up to 10 W CW or pulsed. The RF driver includes pulse modulation capability and provides an output voltage monitor proportional to the output power. The unit incorporates a VSWR fault

BIT indicator that shuts down the output if the load VSWR exceeds 3.0 to 1. The RF driver is designed for a full MIL environment.

Rodelco Electronics Corp.,
Ronkonkoma, NY (631) 981-0900,
www.rodelcocorp.com.

RS No. 233

Antennas

Bidextrous Spiral Antenna

Cobham SASL's AST-2144 Bidextrous spiral antenna provides a pair of same sense circularly polarized apertures in the form factor of a single spiral antenna. Available in a LHCP or RHCP configuration, the AST-2144 provides smooth gain, controlled axial ratio, and repeatable pattern performance over 2 to 18 GHz that is comparable to Archimedean spirals. It achieves a 3 dB gain improvement over 80 percent of the band when used in place of power-divider and single aperture and is sized to be compatible with standard flange mounted four-hole spiral antennas for ease in retrofitting single aperture antennas. The AST-2144 incorporates an integral flat thin-wall radome for basic environmental protection. Applications include: Airborne Radar Warning Receivers; Airborne Direction Finding (DF) Systems; ESM and ELINT Systems.

Cobham SASL,
Lansdale, PA (215) 996-2416,
www.cobhamdes.com.

RS No. 234

Spiral Antenna

This VHF/UHF cavity backed low profile spiral antenna is qualified for airborne application. The unit is extremely lightweight (5.8 lbs) through the use of composite materials for the housing. The spiral antenna employs unique slow wave technologies to increase the efficiency of this extremely electrically small antenna. The antenna is available in phase and amplitude matched sets for interferometer applications or as single apertures for wideband frequency collection sensor. P/N 092-00744 provides wideband, high efficiency performance in an extremely compact package. The antenna mechanical envelope is a 15-inch diameter by five-inch deep cavity. It operates over the 100 to 1000 MHz frequency range with a nominal VSWR of less than 2.5:1.

Cobham Sensor Systems – Sensor Electronics, Baltimore, MD (410) 542-1700,
www.cobhamdes.com.

RS No. 235

Processing Equipment

Prep Tool

The CST-400 (3192-004) All-In-One Combination Prep Tool is designed for use with the LMR-400 low loss coaxial cables including standard LMR, DB, FR, PVC, LLPL and -75 and can also be used for the first strip step on LMR-400-Ultraflex. The new tool provides: a combination feature that allows preparation of LMR-400 cables for either crimp or clamp connector attachment; is suitable for use with virtually all LMR-400 connectors; provides consistently sharp cut of dielectric for best VSWR performance; includes a built-in debur tool eliminating the need for a separate debur tool; and offers rugged, lightweight construction.

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

RS No. 226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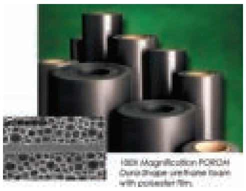
Phase1-63E5

Material

Poron Dura-shape Option

VENDORVIEW



Rogers Corp. has achieved another technical first with its product line of PORON® urethanes. This unique PORON material enhancement, the Dura-Shape™ option, is a layer of polyester sealed between two layers of PORON foam that will help fabricators produce highly accurate gaskets. This new product is the solution that fabricators have been seeking in terms of improved die cutting for high performance gaskets and seals. The "sandwiched" polyester film adds increased dimensional stability to the foam that inhibits it from changing shape during processing. This enhanced feature should allow for faster processing times. In addition to faster processing times, the increased dimensional stability and tougher tear strength of the PORON Dura-Shape option also enables more accurate die-cutting, thereby enhancing product reliability and longevity.

Rogers Corp., Rogers, CT, (800) 755-6766 www.rogerscorp.com.

RS No. 236

Software

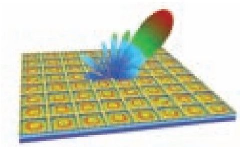
CST STUDIO SUITE Version 2009

CST STUDIO SUITE™ 2009 is the culmination of many years of research and development into efficient and accurate computational solutions to electromagnetic designs. It comprises CST's tools for the 3D EM design and optimization of static to optical frequency applications, as well as synthesis and circuit simulation. All programs are accessible through a common interface, CST DESIGN ENVIRONMENT, which facilitates multi-physics and co-simulation.

CST of America® Inc., Framingham, MA (508) 665-4400, www.cst.com.

RS No. 237

EM Field Solver Update



The new version 5.20 of the EMPIRE XCcel™ 3D EM field solver for the design and analysis of RF and microwave components, antennas, etc., features the Perfect Geometry Approximation (PGA) algorithm to yield highly accurate results for curved and off-axis structures without loss of simulation speed. The on-the-fly code generation for each model and processor produces up to 1,600 million FDTD cells per second on a conventional multi-core PC supporting up to 256 GByte RAM. Other features include an Object Library with 3D, 2D, wire and SMD objects, a Port Library supporting circular waveguides, internal wave guide ports with higher order modes, object snap on edges, corners and midpoint, fast plane wave excitations, superposition of near and far fields and an Update Manager.

IMST GmbH, Kamp-Lintfort, Germany +49 28429810, www.empire.de.

RS No. 238

Sources

Phase-locked DRO Replacement

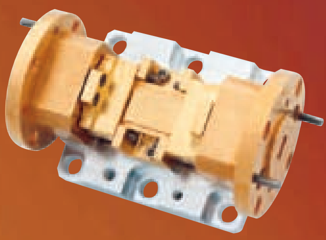
The ESP-100 and ESP-200 were designed as local oscillators in high level mixers designed to test picocell and femtocell base stations. The ESP-100 and ESP-200 operate fixed at 100 MHz and 200 MHz, respectively, and feature extremely low phase noise (<-130 dBc/Hz at 100 kHz, typical). The ESP Series is available with output powers up to +14 dBm, external or internal frequency references, in a small connectorized package, 2.25" × 2.25" × 0.6". The ESP Series frequency synthesizers are ideal for broadband and cellular applications requiring a robust test unit with excellent performance.

EM Research Inc., Reno, NV (775) 345-2411, www.emresearch.com.

RS No. 247

MILLIMETER WAVE COMPONENTS

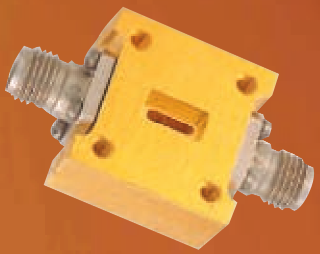
AMPLIFIERS • MIXERS • MULTIPLIERS



AMPLIFIERS

Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	In/Out VSWR (Max.)	Output Power at 1dB Comp. (dBm, Typ.)
JSW4-18002600-20-5A	18-26	34	1.5	2.0	2.0:1/2.0:1	5
JSW4-26004000-28-5A	26-40	25	2.5	2.8	2.2:1/2.0:1	5
JSW4-18004000-35-5A	18-40	21	2.5	3.5	2.5:1/2.5:1	5
JSW4-33005000-45-5A	33-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW5-40006000-55-0A	40-60	18	2.5	5.5	2.75:1/2.75:1	0

Higher output power options available.



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz) RF	LO	IF	Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
LNB-1826-30	18-26	Internal	2-10	42	2.5	25	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	25	45
IR1826N17*	18-26	18-26	DC-0.5	11	9.5	25	25
IR2640N17*	26-40	26-40	DC-0.5	11	9.5	25	25
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20

* For IF frequency options, please contact MITEQ.

MULTIPLIERS

Model Number	Frequency (GHz) Input	Output	Input Level (dBm, Min.)	Output Power (dBm, Min.)	Fundamental Feed Through Level (dBc, Min.)	DC current @+15VDC (mA, Nom.)
MAX2M260400	13-20	26-40	10	10	18	160
MAX2M200380	10-19	20-38	10	10	18	200
MAX2M300500	15-25	30-50	10	10	18	160
MAX4M400480	10-12	40-48	10	10	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	10	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

Higher output power options available.

MITEQ also offers custom designs to meet your specific requirements. For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com

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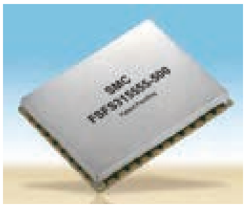
Fast Settling Synthesizers

VENDORVIEW



The FSFS series of surface-mount, fast settling synthesizers is designed for frequency hopping and jamming applications. The FSFS315555-500 is the first model released in the series providing under 50 uSec of settling time when commanded for start/stop and stop/start frequency jumps. The synthesizer tunes in 5 MHz steps within the tuning band of 3150 to 5550 MHz, having spurious rejection of 75 dBc typical. The phase noise is -80 dBc/Hz up to 100 kHz and -100 dBc/Hz at 1 MHz offset from the carrier. This synthesizer requires +5 and +15 V DC for operation and is packaged in a small surface-mount RoHS compliant package, measuring 1.25" × 1" × 0.3".

Synergy Microwave Corp., Paterson, NJ (973) 881-8800, www.synergymwave.com.

RS No. 239

Frequency Source

Model OSC048 is an ultra low phase noise frequency source that is designed and manufactured for harsh tactical radar environments and provides superior performance over dynamic environmental conditions. The 1700 MHz output provides ultra-low phase noise, spurious suppression of -85 dBc, low DC power consumption, and is offered in a compact mechanical footprint. The SSB phase noise profile is state-of-the-art performance for an unheated, statically mounted crystal oscillator.

TRAK Microwave Corp., Tampa, FL (813) 901-7200, www.trak.com.

RS No. 240

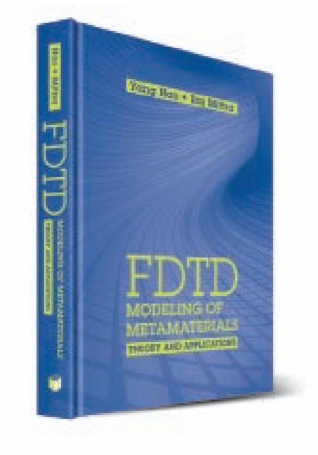
Voltage-controlled Oscillator

The model CRO3160B-LF is an RoHS compliant voltage-controlled oscillator (VCO) in S-band. The CRO3160B-LF operates from 3140 to 3180 MHz with a tuning voltage range of 1 to 4 VDC. This VCO features a typical phase noise of -110 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 23 MHz/V. The CRO3160B-LF is designed to deliver a typical output power of 4.5 dBm at 5 VDC supply while drawing 25 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -13 dBc and comes in Z-Comm's industry standard MINI-16-SM package measuring 0.5" × 0.5" × 0.22". It is available in tape and reel packaging for production requirements.

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

RS No. 241

The Book End



FDTD Modeling of Metamaterials: Theory and Applications

Yang Hao and Raj Mittra

Master powerful new modeling tools that enable one to quantify and represent metamaterial properties with high accuracy. This first-of-its-kind book brings one up to speed on breakthrough finite-difference time-domain (FDTD) techniques for modeling metamaterial characteristics and behaviors in electromagnetic systems. This practical resource comes complete with sample FDTD scripts to help pave the way to new metamaterial applications and advances in antenna, microwave and optics engineering. The book has in-depth coverage of state-of-the-art FDTD modeling techniques and applications for electromagnetic band-gap (EBG) structures, left-handed metamaterials (LHM), wire medium, metamaterials for optics and other practical metamaterials. It also presents conformal and dispersive FDTD modeling of electromagnetic cloaks, perfect lens and plasmonic waveguides, as well as other novel antenna, microwave and optical applications.

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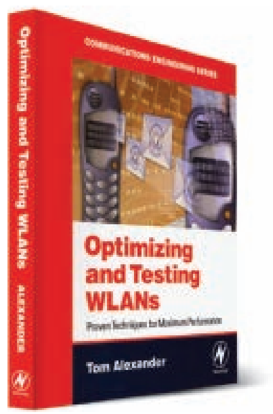

Optimizing and Testing WLANs

Tom Alexander

As Wireless Local Area Networks (WLAN) become increasingly common, it is becoming vital to be able to test them for proper performance and to optimize their operation. This book, written by a member of the IEEE committee that develops WLAN standards, is one of the first books addressing that need. It covers test equipment and methods for the RF (wireless) and physical layers of WLAN, protocols, the application layer and manufacturing testing. The emphasis throughout is on underlying engineering principles along with modern metrics and methodologies, ensuring this book gives both a solid theoretical background along with field-proven techniques and applications.

To order this book, contact:

Elsevier · 11830 Westline Industrial Drive · St. Louis, MO 63146 · (800) 545-2522
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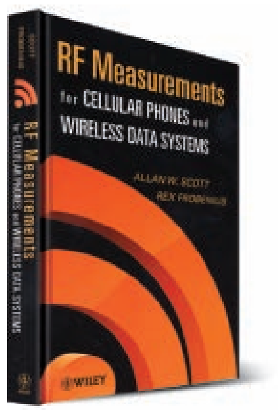

RF Measurements for Cellular Phones and Wireless Data Systems

Allan W. Scott and Rex Frobenius

RF Measurements for Cellular Phones and Wireless Data Systems is a comprehensive source for practical, real-world information on radio frequency (RF) measurements for cellular phones and wireless data systems. It has a review of basic RF principles and terminology, descriptions of RF measurement equipment, an explanation of the RF devices used in cellular phones and wireless data transmission equipment, and information about the testing of RF devices and systems with digitally modulated signals that represent the voice, video, or data carried by RF. It serves well as a guide to cell phone and wireless equipment technology.

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Career Corner

RF and Microwave Engineering May Still Thrive in 2009

While almost all segments of the electronics industry will be flat or decline in 2009, a few exceptions are possible.

Defense sector

Demand for engineers in the defense sector is stable according to the number of positions requiring security clearance. Time-to-hire is still several months. Evidently, RF engineers with matching skill-sets and security clearance are still a scarce commodity.

A recent ABI Research study predicts several electronics markets that will continue to "grow explosively" next year:

Video surveillance and telepresence

Markets for video surveillance and telepresence are expanding rapidly, especially IP cameras and remote medical diagnostics equipment.

Wi-Fi technology for healthcare

Wi-Fi applications for healthcare will continue to expand in 2009 as doctors, nurses and technicians become more mobile, requiring links to medical databases.

RFID technology

The RFID sector could benefit from the tough economic times since RFID tags increase operational efficiency and boost profits. The key application will be inventory control, a key requirement as consumer spending slows.

GPS will continue to grow

This is especially true in the personal navigation devices market, with inexpensive portable units adding new features that could attract new users for services.

Isaac Mendelson
ElectroMagneticCareers.com
Isaac@ElectroMagneticCareers.com

Hiring and Managing RF Engineers

These days there is quite a bit of discussion regarding the shortage of RF engineers in the US. I agree that this is a problem, but I would like to take the discussion in another direction for a moment or two.

RF engineers are a rare breed; most of them work more for passion than for money. In other words, we need to find the engineer that is excited about what our business is doing. In my experience the best way to find the right people is to involve your engineers in the search process as early as possible; excitement is contagious.

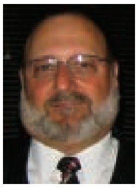
Before you can get to that point, however, you need to develop a clear understanding of what you want the engineer to do:

- Design through simulation
- Design for manufacturability
- Project management through prototype build and test
- Customer interaction
- Sales presentation

Obviously the deeper you plan this individual to perform these engineering roles, the more difficult the search will be. It has been my experience that an RF design engineer with good communication skills is very hard to find. I have known a few and watched some young ones develop. I have seen business develop predominately due to the established rapport between customer and supplier engineers.

There will always be the engineer that can only sit at the computer or work in the lab and they will have their place, but in my opinion the best way to present the quality of your technical product is from the designer.

It is for this reason that I conclude that the search for the qualified RF engineer should be on full time, all the time whether you believe you have an opening at the moment or not. Opportunity happens when it happens, not when we are ready.



David Bernstein
David B & Associates
Former President
EMC Technology/Florida RF Labs

ChinaMW 2009-China`s Premier Microwave and RF Event

China MW 2009
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ChinaMW2009 will be a good opportunity and platform for you to make face to face technical exchanges, business cooperation and trade promotion with China key important microwave & RF customers.

For details, please contact:

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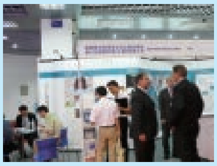







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TEST AND MEASUREMENT

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ACROSS

1 The distortion produced by nonlinear impedance in a component or system when two or more signals with distinct frequencies are present (2 words)
3 A device or impedance that terminates the output of a device or transmission line
5 Mean time between failures
6 The degree to which the impedance of a component differs from the transmission line or component to which it is connected
13 The vector ratio of voltage to current, the reciprocal of admittance
15 Nonlinear vector network analyzer
18 A one-port component that terminates a transmission line
19 Frequency-dependent impedance that is capable of storing but not dissipating energy
20 Third-order intercept point
23 A mapping of the complex impedance plane onto a polar plot (2 words)
24 The control voltage and/or current applied to a device that establishes or facilitates proper operation
25 Energy at integral multiples of the frequency of the fundamental signal

DOWN

2 The property of a material, device or system that impedes the flow of heat (2 words)
4 The ratio of operating to non-operating time for a device (2 words)
7 The real part of the complex impedance of a semiconductor device (2 words)
8 At a given point in a transmission system, the difference between the incident and reflected power (2 words)
9 The ratio of voltage and current at every point along a transmission line on which there are no standing waves (2 words)
10 Error vector magnitude
11 Of or pertaining to magnitude but not phase
12 The ratio of the magnitude of a desired signal to that of noise (4 words)
14 The property of conductors and dielectrics that permits storing electricity when a potential difference exists between conductors
16 A measure of how much better a material is as a path for magnetic flux as compared to free space
17 The ratio of the number of bits in a data transmission that are incorrectly received to the number of bits received (3 words)
21 A circuit that produces a low frequency output signal, typically DC or video, whose amplitude is dependent upon the RF incident power level
22 Electromagnetic compatibility

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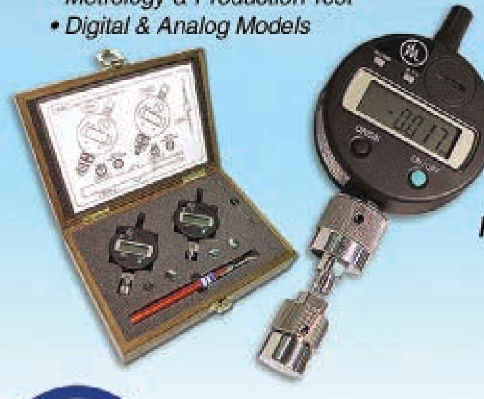

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NEW HIGH DENSITY RF INTERCONNECT SYSTEM

A new high density RF interconnect system using an elastomer interface has been developed to enable smaller connection form factors with low loss from DC to 40 GHz. It eliminates the pin and socket contacts and has no moving parts, a low compression mating force, and is flexible enough for many types of connection systems. It can be used in existing form factors to increase the connection density without changing the current connector type and results in an interconnect with a center-to-center spacing of 0.130".

As the size of components, boards and subsystems decreases, the connection interfaces often become a size limiting component so there is a need to reduce their footprint. There is also a need to increase the connection density in many existing systems or boards to get more data or signals in and out without changing the existing connection interface. A new high density RF interconnect (HDRFI®) has been developed and tested to meet this need and functions as a high performance connector from DC to 40 GHz.

This new connection system transfers high frequency signals through a unique planar interface. This planar interface removes the need for typical pin and socket connections by utilizing a z-axis elastomer to provide the electrical path between the mated connectors. The elastomer is made up of silicone, impregnated with gold plated stainless steel wires that are arranged on a 0.35 mm pitch. When compressed by the mating halves, the gold plated wires mechanically connect the two planar surfaces and create an electrical EMI barrier to provide excellent isolation. The result is a high density, high bandwidth, compact RF interconnect with a center-to-center spacing of 0.130" where the alignment of the connector is independent of the RF path.

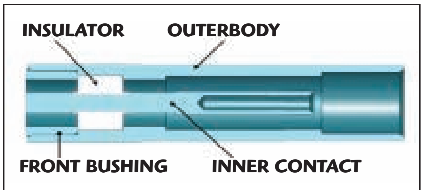

Fig. 1 Cross-section of coax contact.

CONSTRUCTION

The new system uses high frequency low loss coax cable and a unique patented interconnect system to transfer the signal thru the elastomeric planar connection system. The system allows for high frequencies to be transferred with minimal loss and reflections. ***Figure 1*** shows the assembly cross-section for the coax contact.

These coax connections mate against the elastomeric interface to form the connection between the two connectors. ***Figure 2*** shows the cross-section of two connectors and the

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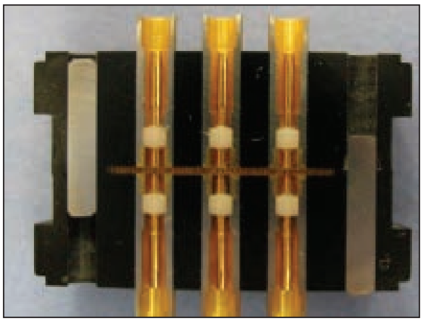


Fig. 2 Cross-section of HDRFI connector.

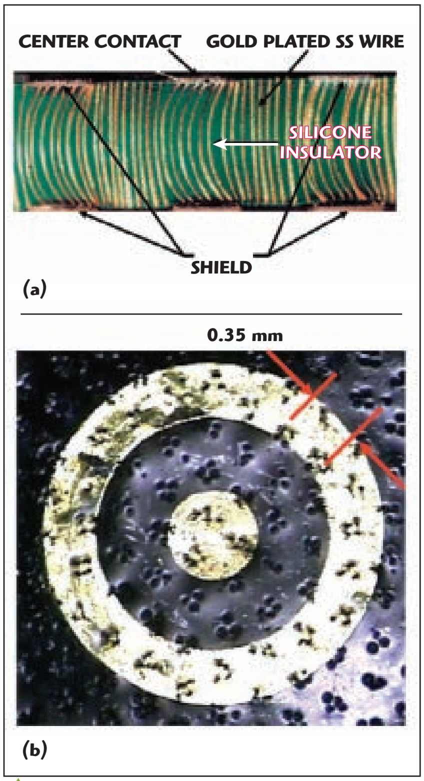


Fig. 3 Cross-section of HDRFI elastomer (a) and metalized surface (b) showing wire clusters.

elastomeric interface. There are no moving parts and only a low compression mating force is needed. The system eliminates stubbing and can be used differentially or single ended. The elastomeric interface is Fujipoly WSC series silicone rubber impregnated with gold plated stainless steel wires. The wires are in clusters that are made up of 3 to 6 wires and the clusters are spaced 0.35 mm apart. ***Figure 3a*** shows a cross-section view of the elastomer where the wires are flexing where the contacts are made. The center contact area and outside shield are indicated. Each wire is individually isolated from each other by the silicon insulator.

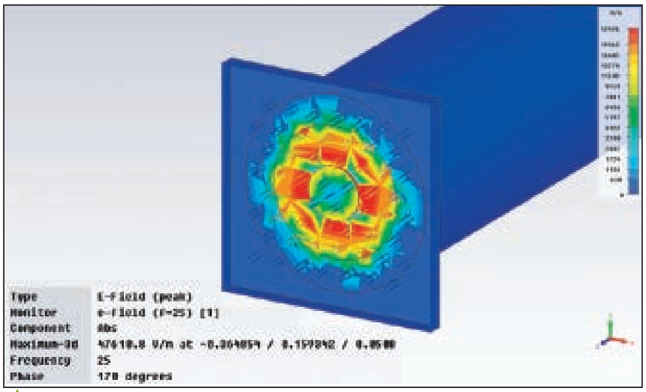


Fig. 4 EM simulation of HDRFI cross-section.

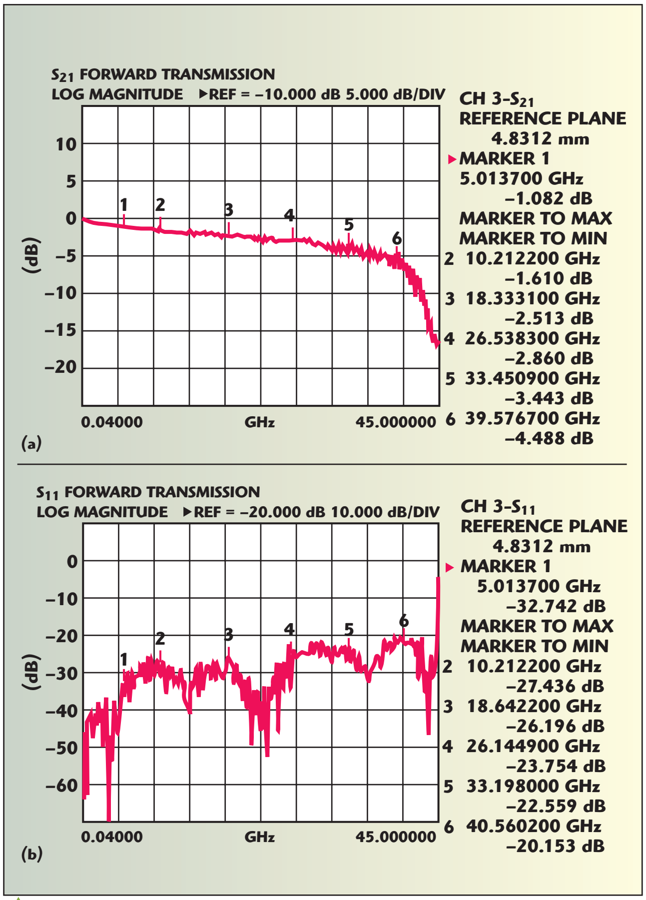


Fig. 5 Transmission (a) and return loss (b) measurements of HDRFI connectors.

The elastomer has a metalized gold pattern on each side to connect to the coax pins on each connector, but the necessary isolation is kept between each connection due to the spacing of the clusters that are not connected to the surface pattern. The isolation between clusters is 100 MΩ minimum. ***Figure 3b*** shows the metalized pattern on the surface and wire ends that protrude through the silicone to make the connection.

MODELING

EM simulations were performed on a model of the contact and elastomer as a single coaxial assembly using Microwave Studio from CST. ***Figure 4*** represents a cross-section parallel to the plane of the elastomer, and is an instantaneous image of the peak field strength in the medium at 25 GHz. The blue color, representing very low field strength, visible everywhere outside the contact shield, is evidence that interference and crosstalk are going to be very small. Modeling of an adjacent pair of signal lines yielded a crosstalk figure of below -100 dB.

PERFORMANCE

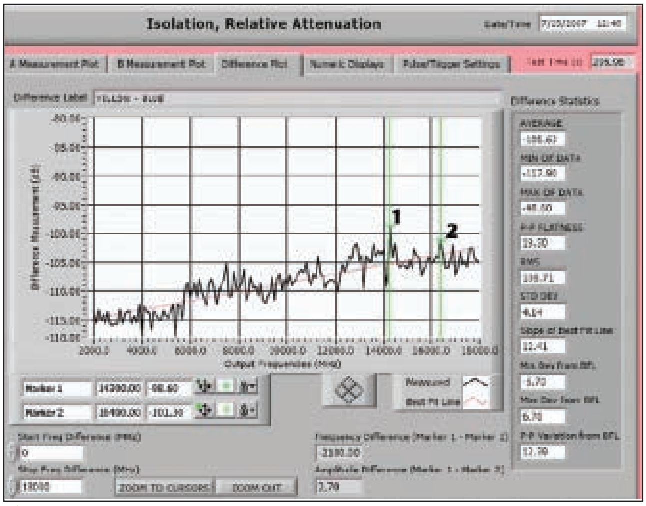
RF measurements were performed on a mated pair of the high density coax connectors with HFF-1087 cable and SMP connectors at the ends to attach to the test leads of the network analyzer. The measured results show excellent transmission (-1.1 dB @ 5 GHz and -4.5 dB @ -40 GHz) and return loss (< 20 dB) values up to 40 GHz, as shown in ***Figures 5a*** and ***5b***, respectively. The plots of the HDRFI mated interface include two feet of 24AWG low loss coax and connector adapters. ***Figure 6*** shows the measured isolation between adjacent connectors was -100 dB at 15 GHz and approximately -95 dB at 40 GHz. The connector was also tested for durability and was shown to have consistent attenuation (standard deviation of 0.05 dB up to 26 GHz) after more than 2000 mating

cycles, four times more than a typical connector system, as shown in ***Figure 7***.

The connector also demonstrated very good signal integrity. The measured eye pattern data using the Tensolite HFF-1087 cable (coax contacts set as differential signals in a RF D-sub shell) is shown in ***Figure 8*** based on the Double Speed Fibre Channel protocol at a length of eight meters without equalization.

Table 1 shows a summary of the electrical performance parameters for the HDRFI assembly. ***Table 2*** shows mechanical specifications for this system and ***Table 3*** shows the environmental testing performed.

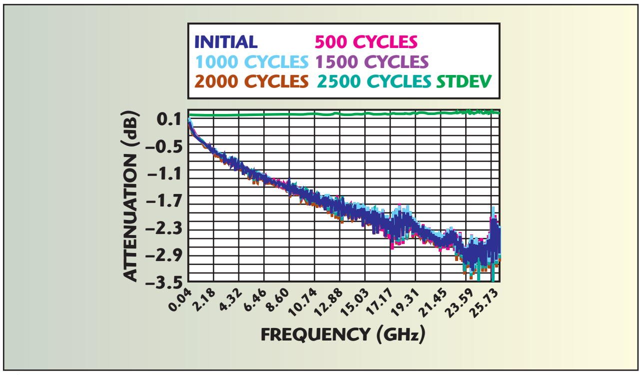
The interconnect system has been used in high density connectors used in high speed digital and many RF applications that call for compact signal routing. Applications include broadband antennas for UAV/ground troop communication, signal intelligence, a phased-array radar program with over 20,000 signals per radar and even the complex harnessing used in some space-weary submarines.



▲ *Fig. 6 Isolation measurement of HDRFI connectors.*

CONFIGURATIONS

HDRFI is made as an assembly in three form factors: D-sub, circular and mezzanine. Custom configurations are also available. The assemblies can be used with a 26AWG



▲ *Fig. 7 Durability test results of HDRFI connectors.*

coax for internal applications or 24AWG for external requirements.

The RF D-sub connector family is made in four different shell sizes and can be used in cable to cable, cable to board or board to board applications. Designed with high performance in mind, the insert arrangements are

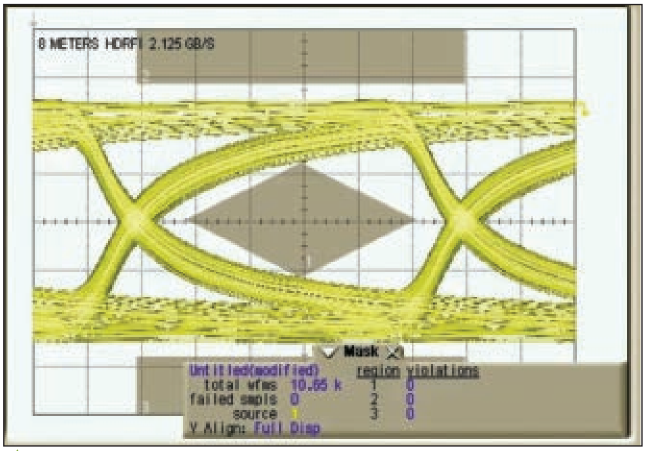


Fig. 8 Signal integrity measurement of HDRFI connector.

TABLE I
ELECTRICAL PERFORMANCE SUMMARY

Insulation resistance	100 mohms min
Dielectric withstand voltage	1,000 Vrms @ sea level
Current rating @ 70°C	1.0 amp
Contact resistance (max)	150 mohms
Impedance, nominal	50 ohm
CW power rating (max)	20 W
Frequency range	up to 40 GHz
Insertion loss (mated pair)	0.25 dB @ 40 GHz
VSWR (max) up to 4 GHz	1.18
4 to 12 GHz	1.25
12 to 18 GHz	1.35
18 to 26 GHz	1.40
26 to 40 GHz	1.45

TABLE II
MECHANICAL AND ENVIRONMENTAL SPECIFICATIONS

Mechanical specifications	
Center-to-center spacing (Custom spacing is available)	0.130" Min
Mating/compression force	0.6 lbs/contact
Durability	2,000 mating cycles
Mechanical shock	tested to 70 G's
Environmental specifications (no changes in performance)	
Thermal shock	-65° to 150°C continuous
Humidity	- 25° to 65°C

TABLE III

ENVIRONMENTAL TESTING

Mechanical shock EIA364,Test #27	70 G's, 10 msec, 1/2 sine, 5 cycles
Random vibration EIA364,Test #29	8.8 G's rms, 50 to 2 kHz, 1 hr/axis, 3 axes
Mixed flowing gas EIA364,Test #65	C12 10 ppb, NO_2 200 ppb, H_2S_{10} ppb, SO_2 100 ppb, exposure 20 days, mated
Thermal shock EIA364, Test #32	-65° to 150°C, 5 cycles, mated
Humidity EIA364 Test #31	25° to 65°C @ 90 to 95% R.H., continuous (thermal cycling) 500 hours, mated
Temperature life EIA364, Test #17	120°C, 500 hours 1.0 amp, mated

maximized to hold more impedance controlled size 16 type RF contacts than other typical D-sub connectors. The HDRFI RF contacts are press-in style and the connectors can accommodate standard D-sub backshells and mounting hardware. The mixed-signal D-sub connector family is a good solution to combine both power and high frequency RF contacts into a standard D-sub shell.

The circular connector family is made for high performance applications. The insert arrangements are maximized to hold more impedance controlled size 16 type RF contacts than any other circular connector on the market today. The product line consists of shell sizes 15 to 25 and is based on the D38999 specification. The HDRFI RF contacts are press-in style and the connectors can accommodate standard D38999 backshells and hardware.

The mixed-signal circular connector family is a perfect solution to combine both power and high frequency RF contacts into the same connector body. The product line consists of shell sizes 15 to 25 and is based on the D38999 specification. The signal pins are size 20, rated to 7 amps and are combined with the HDRFI RF contacts. All of the contacts are press-in style and the connectors can accommodate standard D38999 backshells and hardware.

HDRFI can be customized to fit almost any application, from custom board connectors, to insert arrangements that can have a common ground plane, to having each signal path isolated from each other. It is a high performance, high density connection solution for many applications from DC to 40 GHz. ■

Christopher Tutt *received his training while serving in the US Navy with a background in RADAR technology and fire control systems. He is currently a product manager for Carlisle Interconnect Technologies, St. Augustine, FL. He has been involved in cable, connector and cable assembly designs for 18 years. He currently holds five patents in the interconnect field.*

PHASE MATCHING AND TRACKING OF COAXIAL CABLE SETS

Modern approaches to microwave systems have increased the need for phase matched coaxial cable sets. For example, instead of spinning a large radar antenna to generate a radar image, multiple stationary elements are electronically scanned to generate the radar image. Therefore, each element, or group of elements, is fed through a single cable of a phase matched-phase tracking cable set.

Ideally, each cable in the set has precisely the same phase characteristics as every other cable in the set. That is, the designer would like a phase tolerance to be zero. In practice this is not possible and manufacturers offer a tolerance of plus or minus a "proverbial" mile. The cable manufacturer determines a reasonable match tolerance based on several factors, some of which relate to cable materials and construction, cable length, connector interface and operating frequency. While it is almost always possible to get a smaller match tolerance, the trade off is increased manufacturing time and higher cost.

The manufacturer typically performs the phase matching under room ambient conditions with the cables in a standard configuration. The match may remain constant with temperature or, more likely, change with temperature; the same is true for installation bends. Thus, the achieved match depends upon the configuration and temperature uniformity of the system.

In short, the system designer and cable manufacturer must agree on the value placed on the match tolerance and that match limit will most likely require an additional allowance for any phase change after installation in the final application.

DISCUSSION

Let us examine the influence of several parameters on the closeness of the phase match. Although phase match is used throughout this paper, the concepts are the same for time delay matching, phase offsets, etc.

RAY SCHWARTZ
Cobham DES M/A-COM, Lowell, MA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SMPSM - 60GHz
SMA - 26.5GHz
SSMA - 46GHz
BMA - 26.5GHZ
BMAM - 38GHz
2.92mm - 40GHz
2.4mm - 50GHz
Type N - 18GHz
TNC - 18GHz
In Series Adapters - 50GHz
Between Series Adapters - 40GHZ
Cable Assemblies - 50GHz
THE dyna SPECTRUM
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DYNAWAVE...
offers the highest frequency available for the broadest range of RF and Microwave DC-60GHz Connectors, Interconnects and Cable Assemblies in the industry. From SMPs at 40GHz to delay lines and phase match cables we can fulfill your needs for the most challenging projects. For a comprehensive view of our products and specifications, and to order our 350 page product catalog, please visit our website at www.dynawave.com or contact your local representative.
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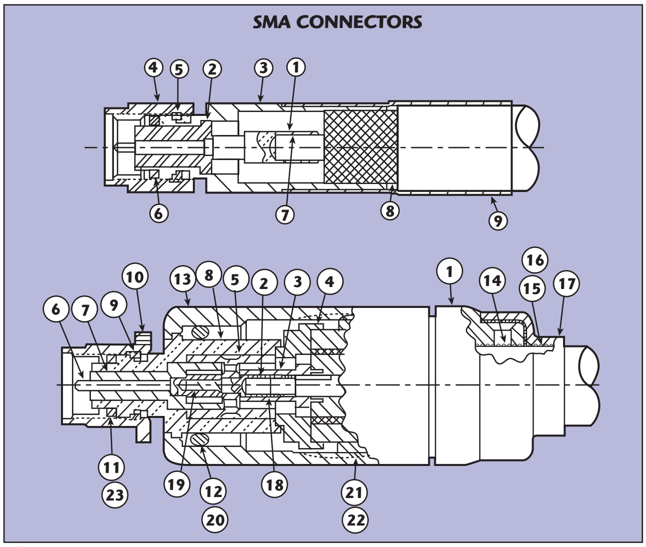
Highest Frequency of Operation

In a given medium the wavelength (λ) is inversely proportional to frequency. At 18 GHz, λ is one eighteenth as long as it is at 1 GHz. From the manufacturer's viewpoint, it can be 18 times more difficult to achieve a given match at 18 GHz as achieving that same match at 1 GHz.



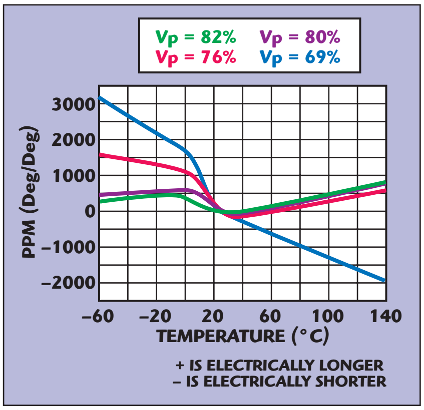
▲ *Fig. 1 Comparison of a simple general-purpose connector (top) and a complex military connector (bottom).*

Connector Construction

A simple connector (see ***Figure 1***) soldered directly on to the cable outer conductor is easy to move. By changing the mechanical length, the phase length can readily be adjusted to a tight tolerance. A more complex design where the outer conductor braid is combed out and clamped over a braid shim is much more difficult to move and make fine adjustments.

Variation of Velocity of Propagation (V_p)

To achieve low loss, coaxial cable manufacturers often use air-spaced dielectrics rather than solid dielectrics.



▲ *Fig. 2 Phase vs. temperature characteristics for representative cable families.*

If the air/dielectric ratio is not exactly the same throughout the cable run as well as from run to run, there will be variations in V_p. In this case, two cables having precisely the same physical length may have different electrical lengths. Clearly, tight control of V_p eases the phase matching problem and results in assemblies having closer physical lengths.

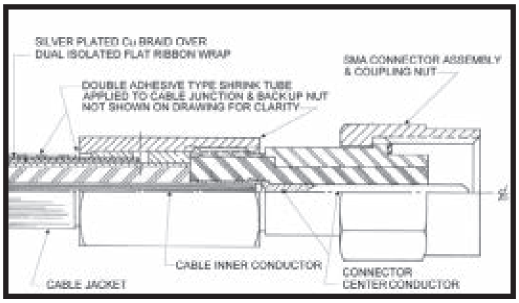
Consider an example: Suppose we want a set of ten-foot assemblies for use up to 18 GHz. Assume that the V_p of the cable can vary over the range 81.0 to 83.0 percent (0.81C to 0.83C where C is the speed of light in free space, approximately 3 × 3 10^8 meters/second). Since λ = C/f where f is the frequency in Hertz, the free space wavelength at 18 GHz is 0.0167 meters. Within our cable with its nominal V_p of 82 percent the effective wavelength is $\lambda_e = V_p\lambda$ or 0.0137 meters long. Our hypothetical ten-foot cable with a nominal V_p of 82 percent is 223.1 wavelengths long. Each wavelength is a 360 degree phase shift so the electrical length will be around 80,316 degrees.

If we repeat the calculation with V_p reduced to its assumed 81 percent lower limit, the effective wavelength is 0.0135 meters. The same ten-foot cables are now 225.8 wavelengths long with a corresponding phase shift of around 81,288 degrees—not very well matched electrically.

It is instructive to calculate the physical length change required to electrically match the second cable to the first. We need to cut it back to be 223.1 wavelengths long. The amount to remove is 0.0364 meter (1.44 inches). Under our assumed condi-

MICROFLEX 170

MICROFLEX 170 is designed for stability & durability under test conditions. A silver plated copper braid is applied over a mylar ribbon which is over a silver plated copper ribbon. The construction of the outerconductor offers outstanding RF shielding characterisitics along wiht stability & isolation. the SMA & Type N connectors are fabricated from statnless steel & the SMA's feature a thick wall design for durability & continued mating cycles.



AFFORDABLE TEST CABLES

DC-26GHz Performance

THICKWALLED CONSTRUCTION OF SMA BODY FOR DURABILTY

CAPTIVE CONTACT & NO RETAINING RING FOR RUGGEDNESS

ISOLATED SHIELDS FOR STABILITY OVER TIME & RF SHIELDING

ELECTRICAL PROPERTIES

Impedance 50 ± 2 OHMs	
Cut off Frequency 33.0 GHz	
Nominal Capacitance 29.4 pf/f	
Velocity of propagation 69.5%	
Max Operating Voltage 1200 Volts RMS	
RF Shielding Greater than 90db	

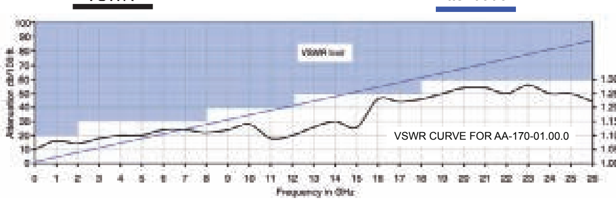
MATERIALS

Inner Conductor Ag Over Cu Clad Steel .036 Dia.
Outer Conductor SIL PL Cu Round Wire Braid Over A Mylar Ribbon Over A Flat SIL PL Cu Ribbon .145 DIA
Dielectric Solid PTFE .116 Dia.
Jacket FEP Teflon .170 Dia.

MECHANICAL PROPERTIES

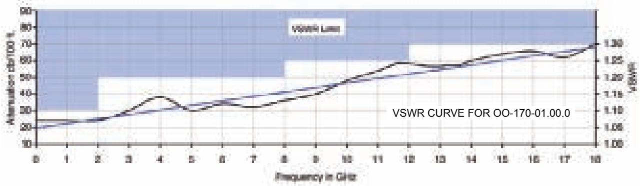
Bend Radius Minimum 1.0 Inch
Temp Range -55ºF/+400ºF
Weight .47 oz/ft

VSWR — Attenuation



Operating Frequency DC-26.0 GHz

VSWR — Attenuation



Operating Frequency DC-18.0 GHz

SMA MALE TO SMA MALE

PART NO.	LENGTH	1-9	10-24	25-49
AA-170-01.00.0	1.0 Ft.	$63.50	$62.25	$61.00
AA-170-01.06.0	1.5 Ft.	$65.00	$63.75	$62.50
AA-170-02.00.0	2.0 Ft.	$66.50	$65.25	$64.15
AA-170-02.06.0	2.5 Ft.	$68.00	$66.75	$65.50
AA-170-03.00.0	3.0 Ft.	$69.25	$68.75	$67.25
AA-170-04.00.0	4.0 Ft.	$72.50	$71.25	$70.50
AA-170-05.00.0	5.0 Ft.	$75.75	$74.75	$73.75
AA-170-06.00.0	6.0 Ft.	$78.50	$77.25	$76.25
AA-170-10.00.0	10.0 Ft.	$89.50	$88.25	$87.50

SMA MALE TO SMA MALE RIGHT ANGLE

PART NO.	LENGTH	1-9	10-24	25-49
AB-170-01.00.0	1.0 Ft.	$88.50	$87.50	$86.50
AB-170-01.06.0	1.5 Ft.	$90.00	$89.00	$88.00
AB-170-02.00.0	2.0 Ft.	$91.50	$90.50	$89.50
AB-170-02.06.0	2.5 Ft.	$93.00	$92.00	$91.00
AB-170-03.00.0	3.0 Ft.	$94.50	$93.50	$92.50
AB-170-04.00.0	4.0 Ft.	$97.50	$96.50	$95.50
AB-170-05.00.0	5.0 Ft.	$100.50	$99.50	$98.50
AB-170-06.00.0	6.0 Ft.	$103.50	$102.50	$101.50
AB-170-10.00.0	10.0 Ft.	$115.50	$114.50	$113.50

SMA MALE TO TYPE N MALE

PART NO.	LENGTH	1-9	10-24	25-49
AO-170-01.00.0	1.0 Ft.	$79.50	$78.50	$77.50
AO-170-01.06.0	1.5 Ft.	$81.00	$80.00	$79.00
AO-170-02.00.0	2.0 Ft.	$82.50	$81.50	$80.50
AO-170-02.06.0	2.5 Ft.	$84.00	$83.00	$82.00
AO-170-03.00.0	3.0 Ft.	$85.50	$84.50	$83.50
AO-170-04.00.0	4.0 Ft.	$88.50	$87.50	$86.50
AO-170-05.00.0	5.0 Ft.	$91.50	$90.50	$89.50
AO-170-06.00.0	6.0 Ft.	$94.50	$93.50	$92.50
AO-170-10.00.0	10.0 Ft.	$106.50	$105.50	$104.50

TYPE N MALE TO TYPE N MALE

PART NO.	LENGTH	1-9	10-24	25-49
OO-170-01.00.0	1.0 Ft.	$90.50	$89.50	$88.50
OO-170-01.06.0	1.5 Ft.	$92.00	$91.00	$90.00
OO-170-02.00.0	2.0 Ft.	$93.50	$92.50	$91.50
OO-170-02.06.0	2.5 Ft.	$95.00	$94.00	$93.00
OO-170-03.00.0	3.0 Ft.	$96.50	$95.50	$94.50
OO-170-04.00.0	4.0 Ft.	$99.50	$98.50	$97.50
OO-170-05.00.0	5.0 Ft.	$102.50	$101.50	$100.50
OO-170-06.00.0	6.0 Ft.	$105.50	$104.50	$103.50
OO-170-10.00.0	10.0 Ft.	$117.50	$116.50	$115.50

SMA MALE TO SMA BULKHEAD FEMALE

PART NO.	LENGTH	1-9	10-24	25-49
AC-170-01.00.0	1.0 Ft	$73.50	$72.25	$71.00
AC-170-01.06.0	1.5 Ft	$75.00	$73.75	$72.50
AC-170-02.00.0	2.0 Ft	$76.50	$75.25	$74.15
AC-170-02.06.0	2.5 Ft	$78.00	$76.75	$75.50
AC-170-03.00.0	3.0 Ft	$79.25	$78.75	$77.25
AC-170-04.00.0	4.0 Ft	$82.50	$81.25	$80.50
AC-170-05.00.0	5.0 Ft	$85.75	$84.75	$83.75
AC-170-06.00.0	6.0. Ft	$88.50	$87.25	$86.25
AC-170-06.00.0	10.0. Ft	$99.50	$98.25	$97.50

SMA MALE RIGHT ANGLE TO SMA MALE RIGHT ANGLE

PART NO.	LENGTH	1-9	10-24	25-49
BB-170-01.00.0	1.0 Ft.	$108.50	$107.50	$106.50
BB-170-01.06.0	1.5 Ft.	$110.00	$109.00	$108.00
BB-170-02.00.0	2.0 Ft.	$111.50	$110.50	$109.50
BB-170-02.06.0	2.5 Ft.	$113.00	$112.00	$111.00
BB-170-03.00.0	3.0 Ft.	$114.25	$113.25	$112.25
BB-170-04.00.0	4.0 Ft.	$117.50	$116.50	$115.50
BB-170-05.00.0	5.0 Ft.	$120.75	$119.50	$118.50
BB-170-06.00.0	6.0 Ft.	$123.50	$122.50	$121.50
BB-170-10.00.0	10.0 Ft.	$134.00	$133.00	$132.00

TYPE N MALE TO TYPE N MALE RIGHT ANGLE

PART NO.	LENGTH	1-9	10-24	25-49
OP-170-02.00.0	1.0 Ft.	$111.50	$110.50	$109.50
OP-170-01.06.0	1.5 Ft.	$113.00	$112.00	$111.00
OP-170-02.00.0	2.0 Ft.	$114.50	$113.50	$112.50
OP-170-02.06.0	2.5 Ft.	$116.00	$115.00	$114.00
OP-170-03.00.0	3.0 Ft.	$117.50	$116.50	$115.50
OP-170-04.00.0	4.0 Ft.	$120.50	$119.50	$118.50
OP-170-05.00.0	5.0 Ft.	$123.50	$122.50	$121.50
OP-170-06.00.0	6.0 Ft.	$126.50	$125.50	$124.50
OP-170-10.00.0	10.0 Ft.	$138.50	$137.50	$136.50

TYPE N MALE TO TYPE N BULKHEAD FEMALE

PART NO.	LENGTH	1-9	10-24	25-49
OS-170-01.00.0	1.0 Ft.	$100.50	$99.50	$98.50
OS-170-01.06.0	1.5 Ft.	$102.00	$101.00	$100.00
OS-170-02.00.0	2.0 Ft.	$103.50	$102.50	$101.50
OS-170-02.06.0	2.5 Ft.	$105.00	$104.00	$103.00
OS-170-03.00.0	3.0 Ft.	$106.50	$105.50	$104.50
OS-170-04.00.0	4.0 Ft.	$109.50	$108.50	$107.50
OS-170-05.00.0	5.0 Ft.	$112.50	$111.50	$110.50
OS-170-06.00.0	6.0 Ft.	$115.50	$114.50	$113.50
OS-170-10.00.0	10.0 Ft.	$127.50	$126.50	$125.50

tions, we require a physical tolerance of ±1.5" to achieve our match. While intuition might say use ±0.12 inches to achieve a good physical match, a tight length restriction only limits the amount of cable that can be used to fabricate the matched cables and does not assure a close electrical match. In fact, as shown in this example, cables with exactly the same length have a phase variation due to different V_ps of approximately 980°.

Temperature

The electrical length of a coaxial cable with PTFE dielectric changes as a complex function of temperature. Often air is introduced into the PTFE dielectric by foaming or expanding it to increase the V_p and reduce the cable loss. How much air and how this is accomplished is the topic for another article.

Typical phase-temperature characteristics are shown in ***Figure 2***. Note that over most temperature ranges the higher V_p cables exhibit smaller phase changes than the lower V_p cables. This is an additional benefit of an air-spaced PTFE dielectric and is also important in phase tracking, which is discussed in the next section. A key observation here is that when fabricating cables of a phase matched set, it is necessary to stabilize the cable and perform all phase matching in a temperature controlled area.

How do we use this data? Suppose two ten-foot assemblies are perfectly matched to each other at room temperature. Now suppose one cable of the pair is used in a 25°C temperature controlled area while the second cable is used in an area where the temperature varies from -55° to +125°C. Using the formulas given above, combined with the phase-temperature changes given in Figure 2, we can determine the electrical length at any temperature.

Consider common RG and semi-rigid cables with solid PTFE dielectric and V_p of 69 percent. At room temperature the phase shift is 95,482°. At -55°C the length increases 3075 ppm (.003075) or by 294°; at +125°C it decreases by 162°. At 30°C, the length decreases by 8.1°. Looking at the situation differently, if we match to a specific phase shift but don't control the temperature, we can have a large phase difference in our cables.

If the dielectric were air-spaced Teflon with V_p of 82 percent, the numbers are quite different. The room temperature phase shift is 80,345°. At -55°C the length increases by 26°; at +125°C it increases by 57°. At 30°C, the length decreases by only 0.8° making thermal control during the phase match operation less critical.

Length of the Cable Assembly

The longer the cable assembly, the more difficult is the matching task. Long cables are difficult to handle and manipulate. They have greater thermal mass and, as illustrated previously, show greater phase changes due to small temperature changes.

Connector Interfaces

It is much easier to phase match cable assemblies when all the cables in the set have the same connectors. That does not mean that an assembly with straight connectors cannot be matched to one with angled connectors; or one with TNC connectors cannot be matched to one with SMA connectors. It just adds to the difficulty and uncertainty of the match. Also, the uncertainty is higher if the assembly is non-insertable; that is, it does not have a plug and jack of the same connector series.

In some applications it is necessary to account for the phase changes that occur during installation. Often the system software does this. It can also be accomplished through the use of phase adjustable connectors attached directly to the cable assembly.

Test Equipment Accuracy

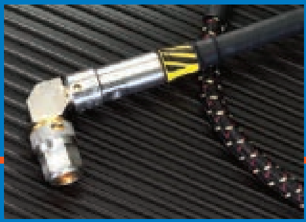
It is highly recommended that a Vector Automatic Network Analyzer be used for the measurement of electrical length. To achieve a high degree of accuracy, the test equipment as well as the cable assemblies must be stabilized in a temperature-controlled room. For best results, do the final phase trimming and ATP testing in the same temperature controlled room. It is also necessary to have phase matched test adapters whenever the cable assembly is non-insertable.

Installation Considerations

It is well known that bending a coaxial cable results in a phase change. To achieve the best match, all cables of a set must be worked on in a standard configuration. They can be coiled on a form, in a "U" or any other convenient shape. However, like all rules there is an exception. When the cables of a matched set are bent into different shapes in their installed condition, test fixtures simulating the installation bends should be used during the matching process.

Mission Critical PERFORMANCE

EW System Interconnects from ***TIMES MICROWAVE SYSTEMS***



Integrated Device Assemblies
- Flat, Equalized, Filtered, Attenuated, Amplified
- Platform-Independent System Design
- Dramatically Boosts System Performance
- Broadband Performance

Multi-Port Interconnects
- 38999 size 8, 12; M8; P8; MMP Contacts
- Blind-Mating, ARINC, Rack & Panel, Custom Shells
- Easy Insertion/Removal, Field Replaceable Contacts
- Rugged, Sealed, Extreme Environment Qualified

Vehicle Mounted/Deployed Antenna
Feeder Cables
- Excellent Long-Term Electrical Performance
- Resists Harsh Treatment and Environments
- NBC Compliant Ruggedization Options
- Suited to COMM, COMMINT, IED, More

PhaseTrack™ for Critical Phase Applications
- Superior Electrical Phase Stability (vs LD PTFE)
- <1.5 ppm/°C
- TF4 Dielectric Technology (no PTFE "Knee")
- Ruggedization Options Available

Blind Mate Antenna Solutions
- Convert Antennas to Blind Mate
- Improve Reliability, Maintainability and Serviceability
- Simplify Mission Equipment Role Changes
- Reduce Loss, Eliminate Cable Loop

Military Low Smoke Cables
- Ideal for Shipboard, Vehicle, Manned Area Use
- Low Loss, Light Weight, Superior RF Shielding
- Fire Retardant (non-halogen), Flexible
- MIL-DTL-17H Qualified

SiO2 (Silicon Dioxide) Cable Assemblies
- Exceptional Phase Stability
- Temperature: -273°C to +600°C
- Hermetically Sealed to 10E-9
- Resistance to Harsh/Extreme Environments

MilTech™ Microwave Transmission Lines
- Flexible, Hermetically Sealed Cables
- Low Loss to 20 dB/100 ft. at 18 GHz
- Replaceable Standard and Self-Locking Connectors
- Aircraft Qualified Worldwide

TIMES MICROWAVE SYSTEMS

ISO 9001 SGS

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MATCHING IN SETS

There are two ways of phase matching sets of cables:

- Matched to a standard
- Matched to other cables in the set

MATCHING TO A STANDARD

The phase standard could consist of either a "Gold" hardware standard or an unchanging software standard, i.e. a known electrical length in degrees at a specific frequency and temperature. Cable assemblies that are phase matched to a gold standard are completely interchangeable. Similarly, cable assemblies that are phase matched to a software standard (known electrical length) are also completely interchangeable. In addition, the use of software standards is more cost effective since they do not require extra material to produce physical standards and they never wear out or degrade with time. With this approach any cable of a set can be replaced without replacing all cables of the set.

MATCHING AS A SET

Cable assemblies matched as a set are only guaranteed to be matched to other cables in the same set. There is no guarantee that the cables in any one set will match those of another set, especially if they are manufactured at different times. This approach results in the lowest cost because cable yields are highest. The drawback is that should any one cable of a set have to be replaced, the entire set may need to be replaced.

SPECIFYING PHASE MATCHED SETS

To produce phase matched sets the manufacturer needs as much of the stated information as the designer can provide. At a minimum, we need to know which cables make up the set, the highest frequency of operation and the desired match. We also need to know if phase standards are required. For critical applications we need to know the bends of the installed configuration so the matching is achieved simulating the installed configuration. This is especially true of long cables where one or more cables might be coiled while others are relatively straight.

PHASE TRACKING

Phase tracking is primarily influenced by four parameters:

- Consistency
- Preconditioning
- Temperature
- Bends

Consistency

Achieving good phase tracking requires cables that behave alike. Manufacturers carefully select and screen the materials that make up its cables and carefully control the manufacturing processes. Thus, each cable run has characteristics quite close to every other cable run. The variation in the phase-temp characteristic is quite small. Without such careful control, the phase temperature characteristic can vary by ± 200 ppm resulting in significant tracking errors.

Preconditioning

Prior to matching the cables of a phase-matched set, it is necessary to thermally stress relieve them to assure good tracking. For example, assume that the first time a cable assembly is exposed to 125°C its phase shift changes by 10 degrees. The second time this might be reduced to 8 degrees; the third time, 7.5 degrees; the fourth time, 7.2 degrees, etc. Thus, thermal cycling artificially ages or stabilizes the assembly. Manufacturers should ensure phase matched cable assemblies are preconditioned prior to final matching.

Temperature Changes

The overall phase tracking due to temperature changes is dependent upon whether all assemblies in the set are exposed to the same thermal environment. The absolute phase change is dependent primarily upon the velocity of propagation. In general, the less the absolute phase changes, the better the phase tracking over temperature. Thus, higher V_p cables are less sensitive to phase temperature changes and track better. This was shown in the examples mentioned previously.

Bends

The overall phase tracking due to bends is extremely difficult to predict. For static installations, it depends upon the number of bends, the angular arc they encompass and the proximity to other bends. If the installation configuration is known in advance, the manufacturer can adjust for it in the fabrication process. For dynamic installations, the tracking depends upon the similarity of the flexure cycle each cable experiences. Often, bundling the assemblies maintains good phase tracking.

Since the tracking deviation is dependent primarily on the similarity of the installation for each cable in the set, the system designer has some precautions to observe. The best phase tracking is achieved when all cables are installed in a similar manner, are exposed to the same thermal environment and/or are flexed together.

CRITICAL APPLICATIONS

For critical applications where the ultimate tracking is required, the cables of the phase-matched set should be braided into a bundle and enclosed within a protective sheath. If possible, the sheath should be a thermal blanket that maintains the temperature near 30°C where phase-temperature sensitivity is minimal.

CONCLUSION

With a little forethought a phase matched set of cables can be specified that will meet most system requirements and not break the budget. Therefore, it is best for the system designer to specify the electrical match parameters to be achieved and let the manufacturer determine how to meet the requirement. Using the physical length as a variable may provide an optimum solution. ■

Ray Schwartz *earned his BSEE, MSEE and PhD EE degrees from Northeastern University. He started his career working at Alford Manufacturing Co. designing slotted lines, impedance plotters (the predecessor of the VNA) and related accessories. He quickly recognized the need for precision connectors and test adapters to permit accurate measurements and concentrated on precision connector interfaces. To this end he participated on both the IEEE precision connector committee and ANSI connector group helping to define and standardize test connector interfaces. After transitioning to Adams-Russell (now CDES M/A-COM) in 1977, he concentrated on the design of high performance coaxial cable assemblies for use in harsh environments as well as the design of cable assemblies specifically intended for use in the test lab. As the Cable Technologist at CDES M/A-COM he now concentrates on unique applications for coaxial cable assemblies.*

CONNECTOR FOR ANNULARLY CORRUGATED 7/8 INCH CABLES

The great diversity of commercially available annularly corrugated 7/8 inch feeder cables presents an increasing logistical challenge to users such as cable manufacturers, network operators and installation companies. Always selecting the right combination from the host of cables and connectors available and making sure that the selected combination is the best for the application is a major problem for customers and suppliers alike.

Consequently, the engineers at SPINNER set about tackling this difficult problem by developing a connector that is not only designed to 'fit' all 7/8 inch cables offered by the leading manufacturers, but will also meet the electrical and mechanical requirements of cables used in mobile communication systems.

The result is the MultiFit™ connector series, which, as the only connector currently on the market that ensures compatibility with all common 7/8 inch cables with annular corrugation, has advantages for both manufacturers and customers. For example, the reduction in the diversity of connector types has a positive effect on warehousing costs, while the connector is also attractive to users who were formerly bound to cables and connectors from one manufacturer.

▲ *Fig. 1 Examples of cables that can use MultiFit connectors.*

DEVELOPING THE MULTIFIT

Initially the questions that were addressed when developing the MultiFit connector series included: Which cables should be catered for? How could the connector adapt to the differences between those cables? And what should be the mechanical and electrical specifications? ***Table 1*** answers the first question as it lists the cables that the MultiFit addresses.

Secondly, the differences between some of these cables are quite significant, beginning with the materials that are used, such as aluminum and copper for the cable outer conductor. Also, the geometry, i.e. the shape of the outer conductor corrugation, varies quite significantly between manufacturers and between materials. The dimensions of nominal sizes and tolerances vary between manufacturers; some cables have a smooth inner conductor while others have a helically corrugated inner conductor. ***Figure 1*** shows some of the variations.

In order to make the MultiFit connector 'fit all', certain design decisions were made.

SPINNER GMBH
Munich, Germany

TABLE I

COMPATIBLE CABLES FOR MULTIFIT CONNECTOR SERIES

Cable Manufacturer	*Cable Type*
Acome	HPL50-7/8 ALU, HPL50-7/8 F and HPL50-7/8 LA
Andrew	AL5-50, AVA5-50 and VXL5-50
Draka	RFA 7/8"-50, RFA 7/8"-50 AL and RFE 7/8"-50
Eupen	EA5-50, EC5-50-A and EC5-50-HF
Hansen	RF 50 7/8"
Leoni	FlexLine 7/8" R LowLoss
LS Cable	LHF 22D, HFC 22D
RFS	LCF 78-50 A, LCF 78-50 L and UCF 78-50 A

The first was that the cable should be prepared by one straight rectangular cut, resulting in a contact of the connector inner conductor on the inside of the tubular cable inner conductor. This means that the connector's inner conductor contact element has to compensate for the differences in the nominal size and tolerance values of the inner conductors of the various cables in order to achieve even contact pressure.

Also, cables with a helically corrugated inner conductor present an additional challenge because their nominal size not only differs greatly from that of smooth inner conductors, but the helical corrugation means that the diameters within the inner conductor itself vary. However, the spring properties of the MultiFit connector's specially designed inner conductor contact, in combination with the bending geometry and the dimensions of the support on which the contact element is fixed, make it possible to compensate for such diameter variations of up to 1.5 mm between the inner conductors. This is almost 20 percent of the inner conductor diameter. Also, the contact element is shaped so as to keep the insertion forces on all cables within a small range regardless of the large number of cable versions.

MAINTAINING CONTACT

In order to meet the exact demands regarding Passive Intermodulation (PIM), the contact force has to be sufficiently high enough and the contact clearly defined, which is why the contact element for the inner conductor used in the MultiFit connector has rounded contact faces. During insertion of the connector to the cable this shape prevents chipping, scratching or deformation, all of which could result in inadequate contact. Furthermore, this special contact design is able to compensate for cable eccentricities to a certain extent. All of these features mean that a high PIM-stability can be achieved under static and dynamic conditions.

The outer conductor contact between the connector and cable is established by clamping the cable's outer conductor. This means that the size of the connector's contact zone has to be matched with its material properties such as the tensile and compressive strength of the cable's outer conductor. The clamping force must be lower than the yield strength of the material in order to prevent damage such as cracking or loose connections due to yielding material.

Therefore SPINNER selected an outer conductor clamping element similar to those used in the company's well known Cut And Fit® connectors. Thus, when the connector is installed, the wave-shaped cable outer conductor is deformed into a cone shape and pressed against the contact surface of the connector. However, the radius of the cable's outer conductor varies with the wave shape, resulting in varying lengths of the cone shape. The cable/connector interface therefore needs to be clearly defined as to have enough material available for a good mechanical and electrical contact for all cable types.

SEAL OF APPROVAL

SPINNER holds the view that the seal between the cable and connector works best if the sealing element is placed on the outer conductor on the cable side, which means that the sealing element design must take the size and geometry of the outer conductor

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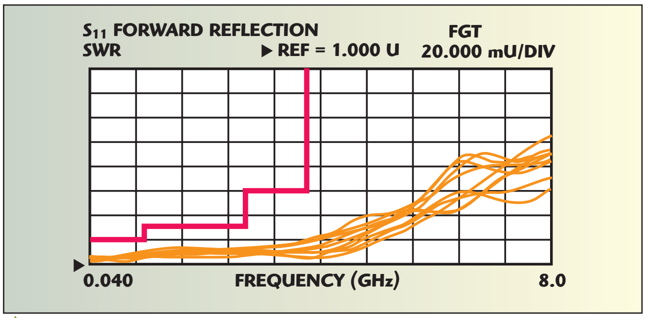
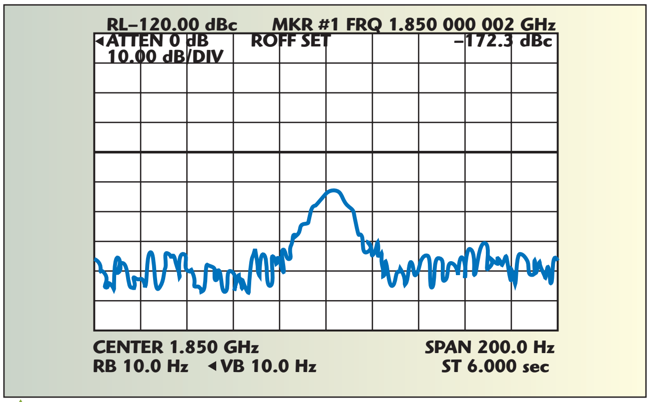
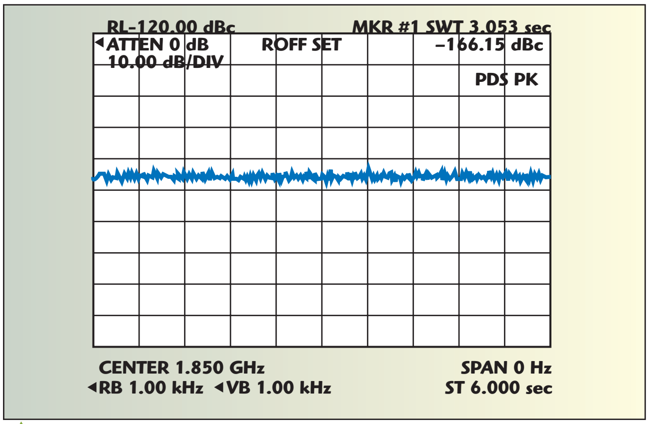


▲ *Fig. 2 Typical VSWR for the MultiFit connector series.*



▲ *Fig. 3 Typical static PIM for MultiFit.*



▲ *Fig. 4 Typical dynamic PIM for MultiFit.*

into account. The corrugation geometry plays an equally important role in the sealing element design.

For the MultiFit connector series, tightness in the transverse direction is generated between the cable's outer conductor and the connector's housing. Because of the different dimensions and shapes of the cable outer conductors, an intelligent sealing element has been designed. The sealing element has to provide enough pressure to provide perfect sealing for any cable type while not producing a surface pressure that is so high that it would require an increased mounting force. Not forgetting that the sealing element also has to compensate for any possible shape irregularity caused by the welding seam.

ACCESSORIES

It is equally important to bear the various cable designs in mind when accessories and mounting tools are developed, whether it is a cable cutting and stripping tool or the saw jig supplied with the connector, which guides a handheld saw. These tools must also fulfill their function with every cable type. On the one hand the cables must not be damaged, while on the other hand the saw jig and cutting and stripping tool must be placed on the cable with as little play as possible. This is necessary in order to ensure an even cable cut because the cable face directly influences the RF space in the connector and thus the connector's VSWR.

When SPINNER developed the RF path for the MultiFit connector series it became clear that even small differences in the cables from various manufacturers result in a reasonable decrease in the electrical performance. In particular, cables with a helically corrugated inner conductor showed this behavior. Nevertheless, the engineers managed to find a geometry for the connector's RF path that can compensate for all of these cable-related factors and keep the connector reflection to an extremely low level with all cable types. VSWR values for the MultiFit connector series are shown in ***Figure 2***.

SPINNER has developed a connector that is not only unique in fitting most common annularly corrugated 7/8 inch cables, but which also meets the demanding requirements regarding Passive Intermodulation (PIM) and VSWR (***Figure 3*** shows a typical static PIM for the MultiFit connector series and ***Figure 4*** shows a typical dynamic PIM). The typical VSWR values for the connector series (for connector interface 7-16) are 1.02 up to 1 GHz, 1.03 from greater than 1 up to 2.7 GHz and 1.06 from greater than 2.7 up to 3.8 GHz.

The connectors also meet the requirements of the relevant standards for electric strength, insulation resistance, etc. For Passive Intermodulation, which is measured according to IEC 62037, Appendix A1, the system reliably meets the highest demands for static and dynamic measurements for all cable types. And while weighing only 150 g and measuring less than 50 mm, the connector features high mechanical stability and meets IP68 requirements.

In its design, important consideration was given to the connector's corrosion resistance as both materials used for cable outer conductors, aluminum and copper, generate different electrochemical potentials in connection with the surface coating of the connector parts. The resulting solution has proved itself by withstanding extensive tests in the salt spray chamber.

CONCLUSION

By taking advantage of SPINNER's 60 years of experience in the RF field, the company has produced the MultiFit connector series that offers the user a high degree of flexibility, excellent quality and easy handling all in one compact, lightweight housing.

SPINNER GmbH,
Munich, Germany,
+49 89 12601-0,
info@spinner.de, www.spinner.de.

RS No. 303

GIGA-LOW µCABLE FLEX CABLES

RFConnext has developed a new class of transmission line products based on its patent pending PMTL™ technology that is a highly scalable interconnect structure. These products can be designed for use in any band from DC to light. RFConnext has developed these products on low cost, flexible PCB materials that have been tested to 50 GHz, and simulations suggest they could work up to 220 GHz and beyond. This wideband technology therefore can be used as a new interconnect medium for high speed digital systems, RF/microwave, and any applications that require a very high signal integrity connection at almost any frequency band for the best signal transmission, and/or for quick connect/disconnect testing connectivity.

The beauty of the technology lies in its ability to be used on current low cost materials such as FR4 or similar to get high speed digital and microwave performance. It uses the current photolithographic processes for PCB fabrication or can be implemented on chip ICs in CMOS processes. It provides high signal integrity transmission with almost no radiation loss, low insertion loss and low cross talk. This will allow moving beyond Moore's Law, enabling increasing density and achieving high speed with a digital pulse of fractional pico sec rise times, on low cost material currently in use.

Fig. 1 Photo of GIGA-LOW series cable.

RFConnext's initial products use this technology to provide a family of products, GIGA-LOW™ (see ***Figure 1***), targeting the testing connectivity, measurement automation and ATE tower top simplification, as well as instrumentation that is used in the process of development, manufacturing, and integration of high speed digital ICs and RF/microwave devices (see ***Table 1***). It will solve many of the test and interconnect problems that currently plague the industry.

GIGA-LOW µCable Flex is a DC to 50 GHz flexible cable that exhibits an excellent phase stability of less than ±2 degrees and amplitude stability of ±0.1 dB for reliable,

RFCONNEXT INC.
San Jose, CA

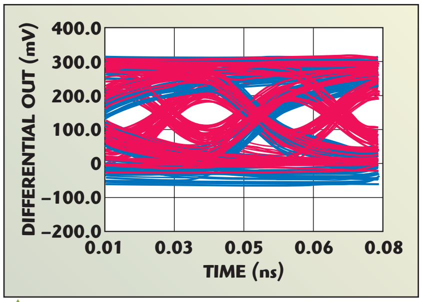


Fig. 2 Simulated EYE diagram using measured S-parameters data of a 6" flexible PMTL to 25 GHz (blue) and to 50 GHz (red).

modular, high frequency and high speed interconnections. It uses the PMTL transmission line technology to achieve unprecedented performance and can handle 2 W of power with a return loss of less than -30 dB and insertion loss less than 0.5 dB (see ***Figures 2*** and ***3*** for performance graphs and ***Table 2*** for complete specifications). This micro flexible cable can be used for mechanical decoupling of test equipment/DUT, and high speed board to board interconnections at single and multi connection levels, and replacing short-range optical links. It provides the industries' first flexible jumper with excellent electrical and mechanical properties with controlled phase, amplitude and impedance for operating from DC to 220 GHz (see ***Table 3*** for a full list of features).

Custom designs with active IC and capacitive and inductive elements are possible with sub bands and various standard connectors. The cable technology is highly scalable, so it can be implemented for longer lengths. Since it uses low cost materials and standard manufacturing processes, it provides low cost, wide-band, flexible interconnections for ICs and boards with stable phase, amplitude and delay. It provides excellent single or differential port isolation required in today's high speed PCB boards.

The cables accommodate mixed signals, control lines and DC and power lines uniformly. Standard lengths are six inches, but other lengths are possible. Since it is array enabled and stackable, it can provide array jumpers and connectors for board edge and top board connectivity. Furthermore, it can be designed for bands from DC to 12, 26.5, 40, 50 and 65 GHz and beyond, with appropriately matched connectors.

RFConnext Inc.,
San Jose, CA
(408) 981-3700,
info@rfconnext.com,
www.rfconnext.com.

RS No. 302

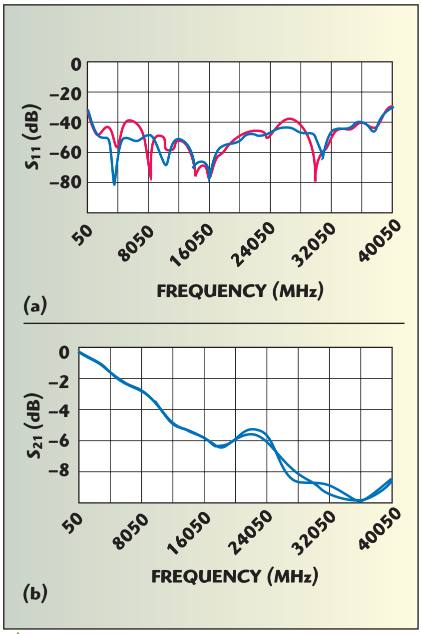


Fig. 3 S_{11} and S_{21} performance of GIGA-LOW series.

TABLE I
APPLICATIONS FOR GIGA-LOW SERIES CABLES

ATE tower tops connectivity
Test socket, device interface
Replacement of short-range optical links (board level)
Optical baseband channel connectors
Board to board edge jumpers/interconnects
Board point to point connections
Sub pSec digital connectivity bus
High signal integrity interconnections
High fidelity testing connectivity
Test fixtures/device interface handlers
Parallel testing of wafers/packages
Flexible high speed data buses
High speed PCBs, flex and rigid, hybrid
Wafer probing/test parallelism
Device and package test sockets
Probe cards/cal cards/interposer
Servers, routers, super computers
SERDES, single lane multi XAUIs
Backplane high speed boards
Phased arrays, antennas
RF/microwave/optical boards

TABLE II
COMPLETE SPECIFICATIONS FOR GIGA-LOW SERIES

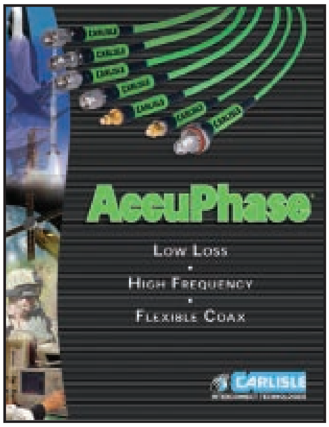
Electrical	***Specification***
Frequency range (GHz)	DC to 50*
Terminal impedance (Ω)	50
Intrinsic impedance (Ω)	50
Connection pattern (mils)	G-S-G, GSSG Dif.
Power handling (W)	2
Amplitude stability (dB)	±0.1
Phase stability (°)	<±2
Intrinsic impedance stability (Ω)	±1
Cross talk (dB)	<-60
Return loss (dB)	<-30
Insertion loss (dB/Lg)	<0.5
Connector type (special**)	SMA/K/2.92/2.4
Mechanical	
Dimensions W x L x H Option A*** (in)	0.05 x 0.040 x 6
Bending radius limit (recommended) (in)	No less than 0.5
Twisting (recommended limit) (°)	180 deg. over 6"
Thermal	
Temperature (°C)	-55 to +155

* can scale to 220 GHz
** Some mod may be required
***Arrays and stack, and other length available by request

TABLE III
FEATURES OF GIGA-LOW SERIES

Single end or high isolation differential pairs
Miniaturized jumper/connectors
High speed interconnect bus
Stacked board high speed interconnect bus
Flexible, twistable, bendable, strand able
Equal delay lines/phase lines/low skew
Stable phase, amplitude, impedance
Low loss, low cross talk
Hard and flex PCB combinations
Mitigate EMI and EMC, TEMPEST
Mitigate signal integrity, board level, system level
Mechanical decoupling connectors

Cables & Connectors Supplement
Literature Showcase

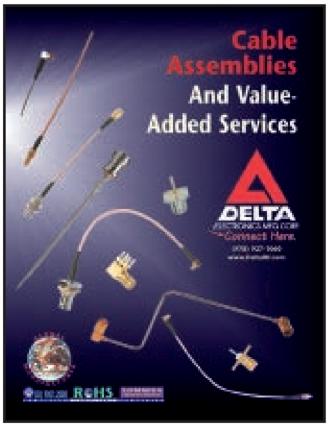


Product Guide

Carlisle Interconnect Technologies has released its 2009 AccuPhase® Product Guide. AccuPhase is a complete line of low loss and phase stable coaxial cable for frequencies up to 40 GHz. AccuPhase, integrated with Carlisle's RF/microwave connectors, was designed and engineered for the highest possible performance. Visit www.carlisleit.com/v2/catalogs.asp for a free download or contact your local sales representative for more information.

Carlisle Interconnect Technologies,
Vancouver, WA (877) 864-8735, www.carlisleit.com.

RS No. 250

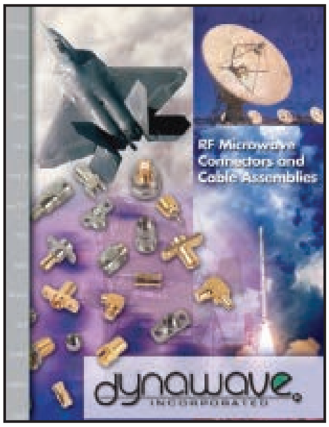


Product Brochure

To assist customers who have a need to streamline their supply chain and logistics, Delta Electronics Manufacturing now offers a broad range of coaxial cable assemblies and other connector-related, value-added component subassemblies. Delta's cable assemblies, incorporating flexible, semi-rigid and hand-formable cables, range in size from micro-miniature to large, high-power types. They cover the spectrum of market needs from high-volume, low-cost assemblies to high-performance, low-volume categories.

Delta Electronics Manufacturing Corp.,
Beverly, MA (978) 927-1060, www.deltarf.com.

RS No. 251

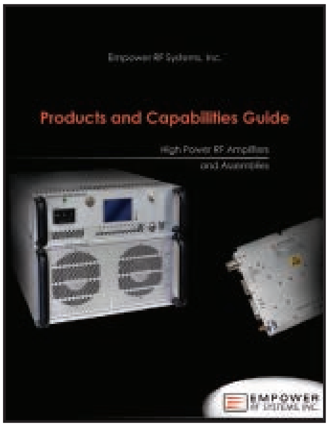


Product Catalog

This catalog details the company's capabilities in the design and manufacture of RF microwave connectors and cable assemblies. The company is a provider of high quality, standard and special RF and microwave connectors, adapters, blindmate interconnecting components and cable assemblies for use in military applications and commercial microwave, RF and wireless industry components. Information on quote requests, ordering and product warranty is also provided.

Dynawave Inc.,
Haverhill, MA (978) 469-0555, www.dynawave.com.

RS No. 252

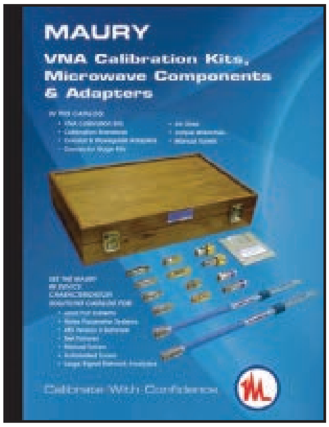


High Power Broadband RF Amplifiers

Empower is pleased to present its updated Products and Capabilities Guide. This brochure is a comprehensive overview of the company's capabilities and a listing of its most popular amplifier products. With products that cover from 150 kHz to 6 GHz and an extensive library of building block designs, there is an array of catalog standard and semi-custom solutions available to consider. This brochure will be especially useful for buyers, sales reps and engineers.

Empower RF Systems Inc.,
Inglewood, CA (310) 412-8100, www.empowerrf.com.

RS No. 253



Components Catalog

Maury has a 146-page catalog covering the company's entire line of precision coaxial and waveguide VNA calibration kits, microwave components and adapters, manual tuners, torque wrenches and connector gage kits. Entries feature detailed specifications, dimensional drawings, photographs, flange diagrams, ordering information and key reference materials. The catalog provides everything engineers need to find the best components for their applications. An interactive version of the catalog is available on the company's web site.

Maury Microwave Corp.,
Ontario, CA (909) 987-4715, www.maurymw.com.

RS No. 254

Product Catalog

MIcable Inc. produces a wide variety of high quality coaxial cable assemblies with flexible, conformable, and semi-rigid cable and customer specified connectors. The company offers prototypes or volume quantities, all fully tested up to 40 GHz and delivered on time. The product brochure highlights a few of the company's products along with providing performance data. For more information, call 86-591-87382855 or e-mail: sales@micable.cn.

MIcable Inc.,
Fuzhou Fujian, China 86-591-87382855, www.micable.cn.

RS No. 261

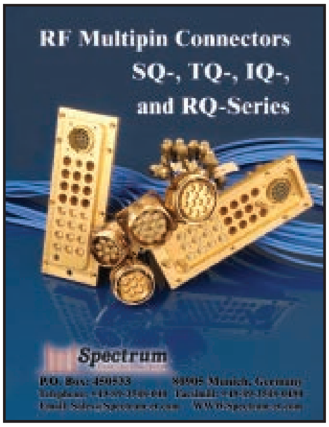
Cables & Connectors Supplement
Literature Showcase

Product Brochure

San-tron Inc., a manufacturer of RF coaxial connectors and cable assemblies, has announced the release of the company's "RF & Microwave Coaxial Connectors and Cable Assemblies" brochure. The brochure outlines its entire product offering, categorized by connector types. Connector offerings include, but are not limited to, SMA, N, BNC, TNC, HN and 7/16 connectors. Adapters, cable assemblies and custom specialty connectors are also featured. The brochure is now available for download on the San-tron web site, www.santron.com.

San-tron Inc.,
Ipswich, MA (978) 356-1585, www.santron.com.

RS No. 255

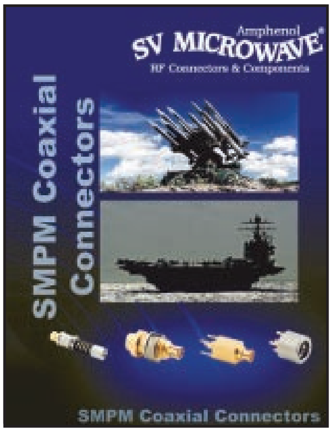


RF Multipin Connector Catalog

This 52-page publication offers the company's solution to the problem connecting and disconnecting microwave assemblies, including threading and unthreading, torquing and untorquing connectors quickly and easily and in confined spaces. The Multipin Connectors are available with 4, 7, 8, 12 and 23 coaxial inserts. Up to 23 microwave cable assemblies are packaged in one fairly small-sized connector, enabling connection and disconnection in seconds and without the need for a torque wrench or safety wires.

Spectrum E.T. GmbH,
Munich, Germany +49 89 3548040, www.spectrum-et.com.

RS No. 256



Product Catalog

SV Microwave released its new SMPM catalog. The new catalog features detailed information on SV's entire collection of SMPM coaxial connectors, including technical specifications, drawings and part numbers. SV Microwave SMPM connectors, a push-on design, provide microwave performance through 65 GHz.

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

RS No. 257

Product Brochure

This brochure introduces the new 190E Series Phase Master® product: highly shielded, phase stable assemblies. An enhanced, multilayer shield construction yields significantly increased shielding effectiveness and increased product durability, especially with regard to torsion and connector retention, in addition to a high level of phase stability vs. temperature and flexure. Graphs, mechanical and electrical specs, and ordering information are also included.

Teledyne Storm Products,
Woodridge, IL (630) 754-3300, www.stormproducts.com.

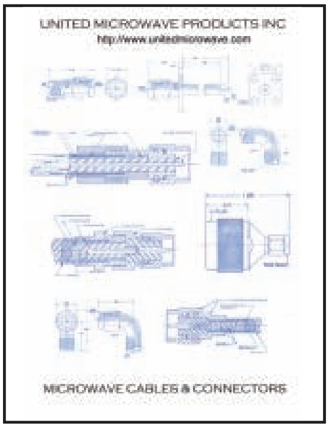
RS No. 258

Product Brochure

This brochure provides a brief, descriptive overview of the LMR® family of cables and connectors, including the acclaimed Advantage™ series. The brochure also includes T-RAD® leaky feeder cable for interior coverage solutions, SilverLine™ test cables including SilverLine QMA and SilverLine TuffGrip™ and also TCOM flexible low-PIM cables. LMR cables are flexible, non-kinking low loss RF transmission line cables that utilize easy-to-install connectors.

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

RS No. 259



Cables and Connectors Catalog

United Microwave's 64-page two-color catalog features a full spectrum of connectors, adapters and RF microwave cable assemblies. The catalog contains flexible cables featuring SMA types to 26 GHz, type N and TNC cables to 18 GHz and millimeter types to 65 GHz. Performance charts, mechanical and electrical specifications and pricing are published within the catalog to provide more information to the customer in both connector and cable types.

United Microwave Products Inc.,
Torrance, CA (310) 320-1244, www.unitedmicrowave.com.

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Cables & Connectors Supplement
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