Vol. 49 • No. 3

March 2006

Microwave Journal

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Anechoic Chamber Measurement Improvement

RWS 2006 Wrap-up

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NSP2200-NVG	0.1–22	30	2.75	4.5	2.5:1	10
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NSP4000-NFG	0.1–40	22	3	5	2.5:1	8
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NSP1800-PFG	0.3–18	18	2.75	8	2.5:1	20
NSP2000-PFG	0.3–20	18	3	8	2.5:1	20
NSP2200-PFG	0.3–22	18	3	8	2.5:1	20

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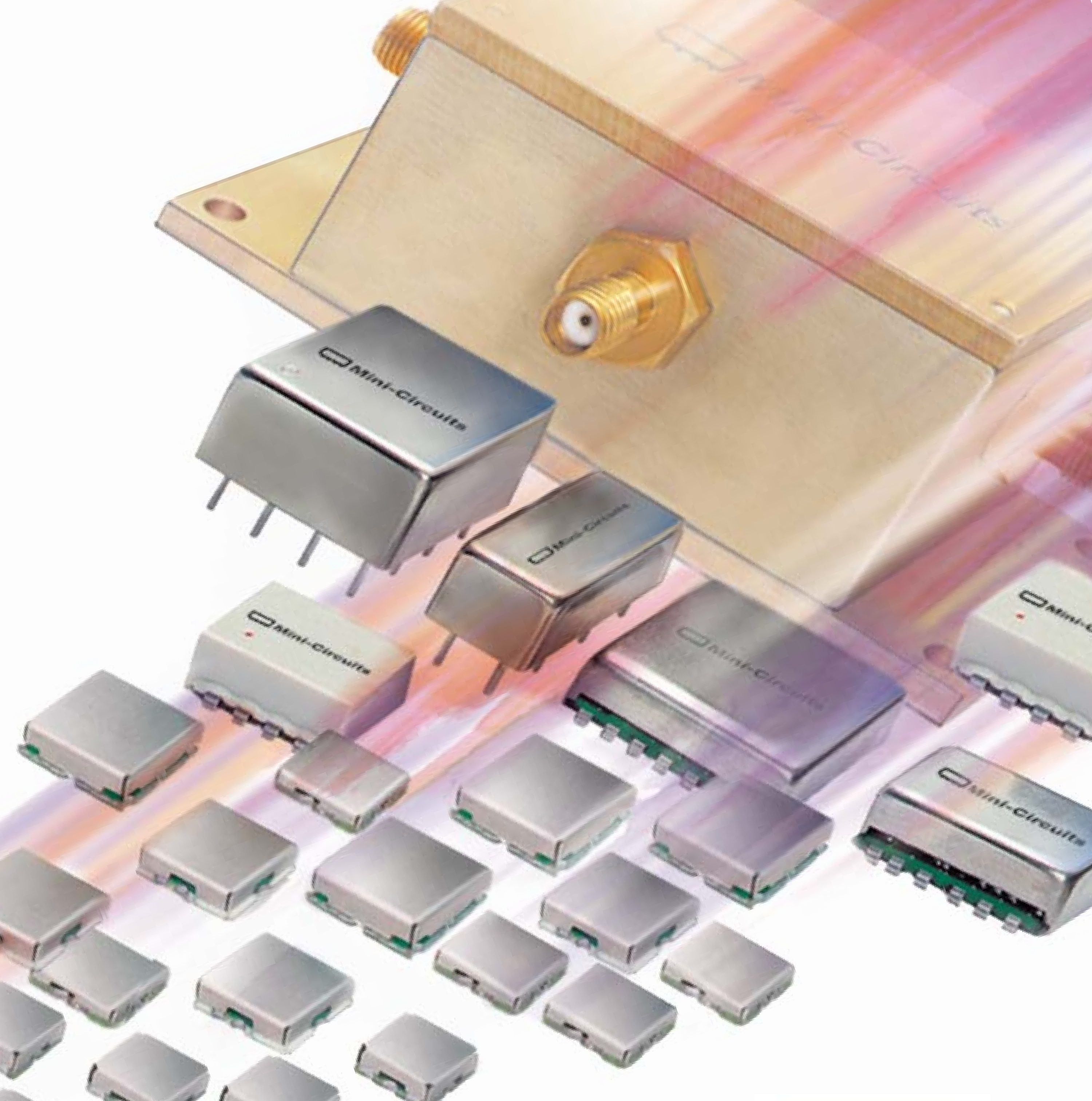

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Microwave Journal

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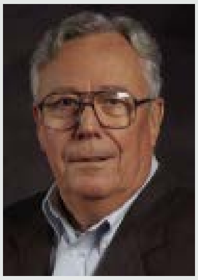
The editorial staff here at *Microwave Journal* is pleased to introduce a new departmental feature to the print version of our publication. "Ask Harlan," a technical question and answer session with Harlan Howe, Jr., an industry veteran and long-time *Microwave Journal* editor, has been a regular part of our web site (www.mwjournal.com) for almost two years now. In an effort to better combine the editorial content of our magazine with our newly developed and retooled on-line presence, we have decided to develop Harlan's RF and microwave engineering advice into a monthly feature.

Beginning this month, Harlan has selected one question from his "Ask Harlan" column to be featured in the magazine. Please visit www.mwjournal.com/askharlan to provide an answer to this month's featured question (see below). Harlan will be monitoring the responses and will ultimately choose the best answer to the question. Although all of the responses to the featured question will be posted on our web site, we plan to publish the winning answer in the May issue.

The winning response will win a free book from Artech House, along with an "I Asked Harlan!" t-shirt. In addition, everyone who submits a legitimate response will be sent an "I Asked Harlan!" t-shirt.



Harlan Howe, Jr. *received his BS degree in optics from the University of Rochester in 1957. He has been actively engaged in the microwave industry for 48 years, first as a design engineer and then as an engineering manager. In 1990, he became the publisher/editor of* Microwave Journal. *He retired as publisher in 2001, but remains the editor. He is a Life Fellow of IEEE, past president of MTT-S and the recipient of an IEEE Third Millennium Medal in 2000 and the MTT-S Distinguished Service Award in 2005.*

Richard Chong from Asia Satellite Telecommunications Co. Ltd. has submitted this month's question:

Dear Harlan,

I recently came across the term "modulation loss" in the receiver portion shown in the (satellite) link budget. When I check my resources, however, I cannot find a proper definition. Here are my questions:

1. What is the definition of "modulation loss"?
2. Is there a theoretical number associated with each type of modulation scheme (or just a receiver type dependent number)?
3. Where can I locate a table summarizing the "theoretical" modulation loss versus types of modulations, if any?

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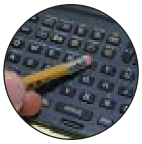

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April 24–25, 2006 • Steventon, Oxfordshire, UK
www.armms.org

Asia-Pacific Microwave Photonics Conference (AP-MWP 2006)
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May 1–4, 2006 • Munich, Germany
www.amta.org/europe

26th European Telemetry Conference (ETC 2006)
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Garmisch-Partenkirchen, Germany
www.etc2006.de

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■ **Contact:** University of Oxford Continuing Education, 1 Wellington Square, Oxford, OX1 2JA UK +44 1865 270360 or e-mail: anthony.santiago@conted.ox.ac.uk.

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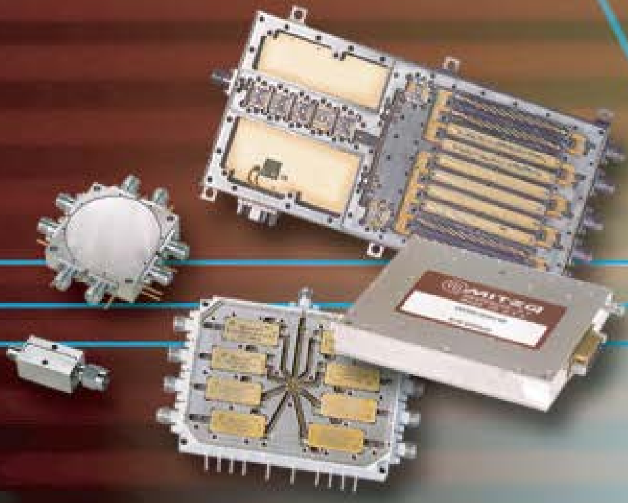

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SYNTHETIC INSTRUMENTS: A NEW HORIZON

Modular test components have been with us for many years in many forms. Going back to the early '70s I can remember HP BWO oscillator/sweeper mainframes with their plug-in modules to address the various extremely high frequencies above 1 GHz. While this modularity in test equipment exists today, a significant new aspect is now sweeping across the landscape — the ability to configure modular components to emulate the complete functions of traditional box instruments and in many cases that of complete test systems. The purpose of this article is to further explore what we mean when we talk of these synthetic instruments, where we might want to apply them and what some of the significant trade-offs are.

Before we can begin to explore what we can do, why we would do it and what the advantages are, we should start with some definitions of terms. Appropriate to the way we work today, an appropriate definition from Wikipedia reads like this: "It describes a functional mode or personality component of a synthetic measurement system that performs a specific synthesis or analysis function on a device under test (DUT) using specific software running on generic, non-specific physical hardware. Typically the generic hardware is a dual cascade of three subsystems: digital processing and control, A/D or D/A conversion (codec) and signal conditioning. One cascade is for stimulus, one for response. Sandwiched between them is the device under test (DUT) that is being measured." How we achieve this synthetic instrument (SI) or synthetic measurement system (SMS) will be further explored here.

Today we can utilize components from three standards-based approaches, as well as non-standards-based approaches to achieve an SI. What is critical to a successful SI implementation is not the standard the hardware is based on, but the support available from the manufacturer and the design of the software architecture the system is implemented in.

Most of us are familiar with VXI,™ as this standard has been available for over 20 years. It has only been in the last few years, however, that significant numbers of microwave components have become available in this format. VXI has the advantage that a large installed base of components are available to draw on to build an SMS.

More recently a lot of interest has been focused on PXI,™ as it offers to be a lower cost, more convenient standard to work in and offers

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Lowell, MA

built-in convenience of working inside a PC. While initially focused on more traditional data acquisition tasks, vendors are increasingly offering higher frequency building blocks that users can now begin to use to assemble a viable SI in the microwave regime.

Most recently, with ratification in late September of last year, a new microwave oriented standard has become available — LXI.™ With a large group of the most prominent microwave instrumentation companies behind it, and building off of 1G Ethernet, LXI has the potential over time to replace much of the GPIB instruments we have all become familiar with. LXI also incorporates a number of triggering capabilities, including IEEE-1588 Precision Trigger Protocol (~200 ns jitter) and inter-unit communication features with performance characteristics exceeding those of the other two standards mentioned here.

Since an SI or SMS is not restricted by definition to any specific hardware standard, we may also construct a system using a mixture of the previously mentioned three standards, along with standard instrumentation or other hardware that does not conform to any specific "system" specification. In cases like this, the system integrator will of necessity take on the responsibility for any software required to construct a functional SI or SMS.

We will more fully explore the implications of the software task in building an SI or SMS, but to date be aware that none of the hardware systems standards, VXI, PXI or LXI, address software much above the driver level, and certainly not sufficiently high enough to insure a successful SMS implementation. This is still an open area of discussion and the responsibility of the system integrator.

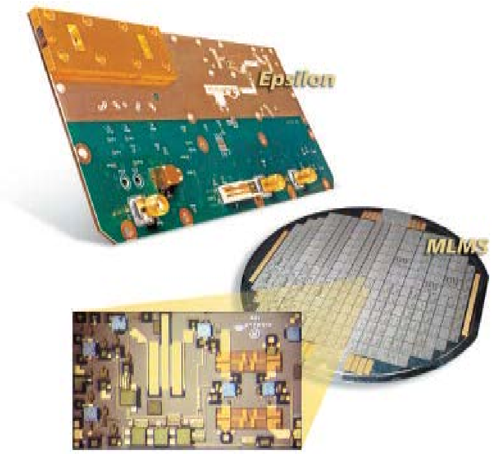
WHAT CAN WE IMPLEMENT WITH SYNTHETIC INSTRUMENTS

If we take a brief look at some of the elemental functions available in VXI, PXI or LXI, the question arises — what can we accomplish of significant value? Clearly the hardware vendors believe that the building blocks that are available will hold our attention longer than the intellectual satisfaction of making a simple power or voltage measurement. Let us now take a closer look at what can be accomplished.

Today, we can purchase a number of items: mass interconnects, switching and scanning units, power supplies, digital I/Os, counter/timers, A/D, D/A, signal conditioning and signal generation. Announced products include wideband up and down frequency converters as well as high performance wideband arbitrary waveform and signal generators.

To demonstrate the utility of the SI or SMS approach we can illustrate how several popular, powerful standard instruments can be implemented using this modular approach. Using a single RF source, a down converter, signal conditioning and an A/D module, we have all of the hardware we need to implement a generic spectrum analyzer, as shown in ***Figure 1***.

To then build on this approach, let us look at one of the most fundamental, yet high performance instruments we commonly use, a vector network



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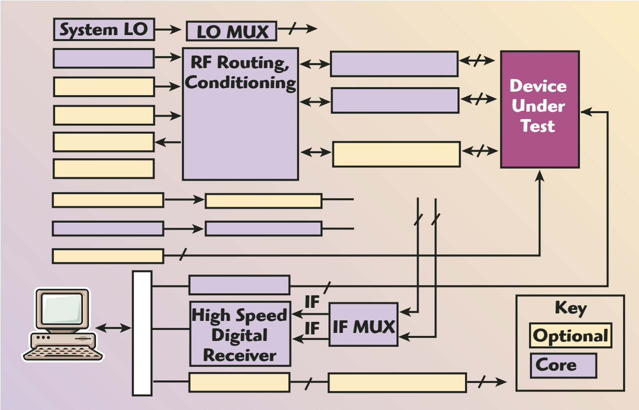
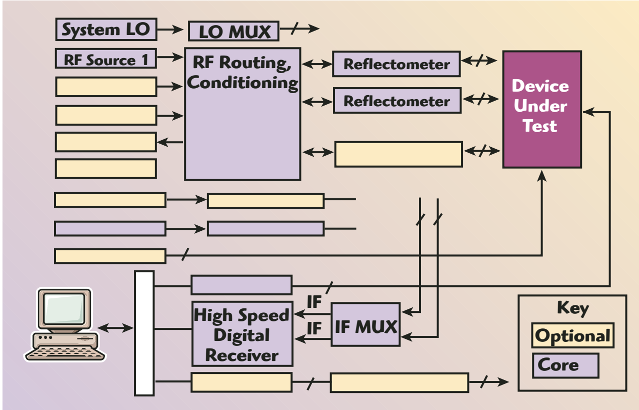


▲ *Fig. 1 An SI generic network analyzer block diagram.*



▲ *Fig. 2 An SI vector network analyzer block diagram.*

analyzer. We can construct this from a combination of signal generators, down converters, signal conditioning and A/D modules, with the application of a suitable amount of software. A representative block diagram is shown in ***Figure 2***.

Using this same block diagram, but some additional signal conditioning at RF and IF, we can achieve a noise figure analyzer. As a final demonstration of the utility of this approach, if we add pulse generation and timing modules, we can convert our CW network analyzer to a highly capable pulsed network analyzer, as shown in ***Figure 3***, or a pulsed power meter.

TRADE-OFFS OF SI vs. TRADITIONAL INSTRUMENTATION APPROACHES

Given the above examples of the flexibility and re-usability of the hardware modules needed to implement a broad spectrum of instruments, why would this not be our primary approach? As a wise man was heard to

▲ *Fig. 3 An SI implementation of a pulsed VNA.*

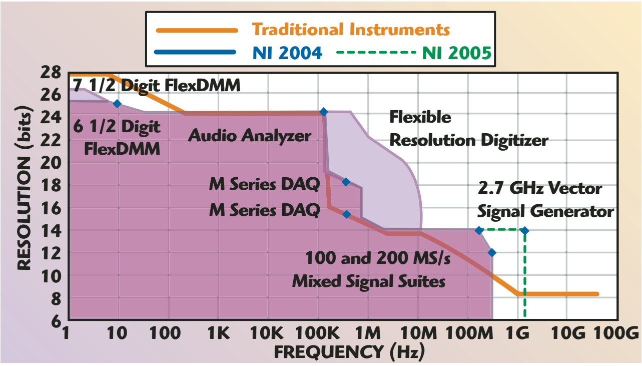
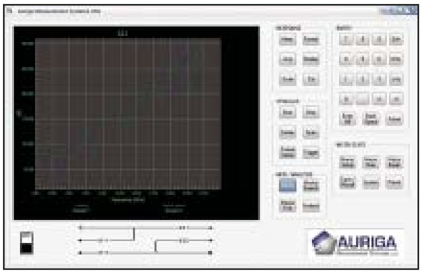


Fig. 4 SI capabilities vs. traditional instrument approaches.

say, there is no free lunch, and that is true here as well. While we can achieve a number of different instrument/measurement capabilities in a compact format in SI, it comes at the cost of in general a much more significant software task for the end user or system integrator and generally a much longer time/measurement. As an example of the latter characteristic, which admittedly is easier to quantify, the above SI VNA is capable of generating a complete set of the four S-parameters at a given frequency, fully error corrected, in approximately 200 ms. That is in contrast to the capability of today's standard, one-box VNAs of making the same measurement in ~200 µs. To quantify the former characteristic of a much greater software task, we can get a measure of that, in that at present there is only one commercially available SI VNA, and a large number of traditional VNAs from a number of suppliers.

We have now seen an example of how, with minimal hardware changes, we can develop several standard instruments. We need to explore when SI or SMS are appropriate and what trade-offs are involved. To help understand the trade-offs, let's examine why PXI (see ***Figure 4***), VXI and now LXI instruments have been developed. VXI is the oldest standard, going back to the early 1990s and is based on earlier work on the European standard VME bus architecture. PXI was first standardized in 1997 with the intent to leverage off of the growing popularity of using PCs in the ATE environment. All three standards aim to provide a degree of modularity not available in traditional test instrumentation. Up to the last several years that was essentially the goal of PXI and VXI, and although there were several attempts at SI early on, they struggled due to the state of computer science and hardware. LXI is the first hardware and software standard developed with SI and SMS fully in mind. High speed communications, hardware and software triggering and software driver architectures are all incorporated into the standard, as well as a high degree of self and system discovery.

In broad general terms, what we gain from SI or SMS is a much more modular system architecture and the ability to rapidly reconfigure the hardware to meet the task at hand. Due to this modular approach, we can, to a much higher degree, acquire "just enough test." The test engineer



▲ *Fig. 5 SI VNA software interface panel.*

configuring the test system can specify at a much lower level the required performance. As an example, if our application only requires 60 dB of dynamic range, we can choose a 12-bit digitizer as a system resource. As an example, essentially all commercial spectrum and network analyzers contain 14- to 18-bit digitizers, and so have more "test" than our supposed application. Additionally, if our requirements change or better hardware becomes available, we can upgrade just this 12-bit digitizer by only replacing that item. With proper system and software design, our application code will continue to run with the new digitizer with no additional changes. This flexibility allows our test system to more closely track the state of the art, as it is expected that manufacturers will be able to introduce modular components more quickly to the market as compared to the development time required for fully configured traditional "box" instruments.

What do we give up with SI? Unfortunately, as with most things, there is a price to pay. In the case of SI and SMS, the price is generally slower measurements and an increased software development task. As we showed earlier, the advantage of dedicated hardware, execution from firmware and a tight coupling between the hardware and firmware as found in traditional instruments results in higher measurement speeds. Also, since in many cases the calibration routines, measurement science and the integration between the various modular pieces is now the responsibility of the system integrator, much more software will have to be developed. Vendors are certainly working hard to minimize this impact, but the manufacturer of that digitizer cannot assume responsibility for all of the potential "instrument" applications. While they will surely develop applications that they may be familiar with, the balance will fall to the end customer to complete.

SI- and SMS-based systems as configured today do not have a convenient hardware-based control or display panel as H-P's MMS solutions offered. Here, we look to use the host PC display and controls as a convenient interface. ***Figure 5*** shows just such a display panel developed to allow convenient operator interface to an SI-based VNA.

One of the side benefits we have noticed in our lab is that since so many of today's instruments basically expect a mouse to be available to interact with the instrument GUI to access many functions not accessible from the traditional pushbutton panels, we often have had up to four rodents wandering about the workbench. Significant time has been involved in locating the correct rodent

TABLE I
TRADITIONAL vs. SI COST COMPARISON

Instrument	Incremental SI Cost ($)	Incremental Traditional Cost ($)	Running Total SI Cost ($)	Running Total Traditional Cost ($)
Network analyzer, 20 GHz	100,000	77,849	100,000	77,849
Spectrum analyzer, 26 GHz	15,000	55,910	115,000	133,759
Noise analyzer, 26 GHz	10,000	57,057	125,000	190,816
Pulse power meter, 18 GHz	30,000	7,830	155,000	198,646

SI costs based on Auriga products, traditional on Agilent E8362B, E4440A, N8975A and EPM-P products

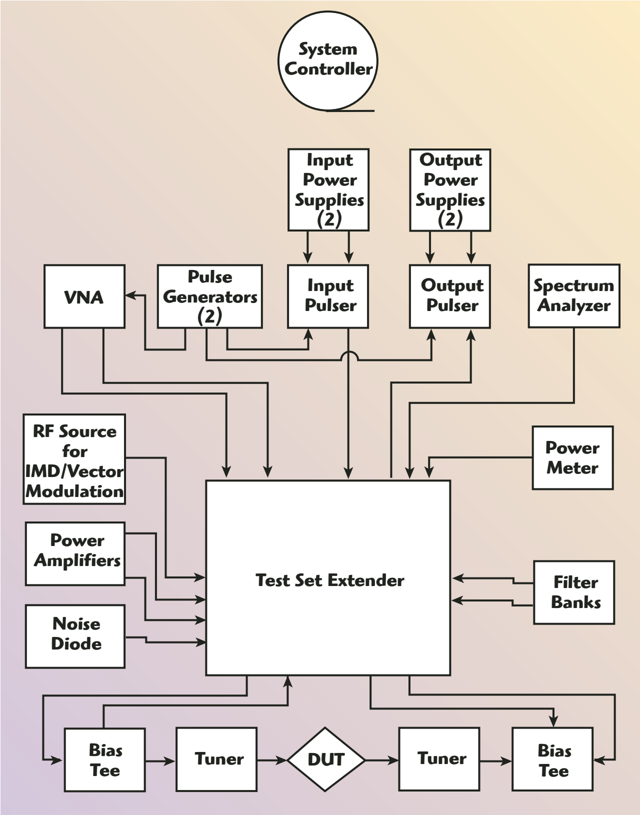
to control the specific instrument we are looking at. With an SI solution, the PC is the only device that requires a mouse; just think of the cost savings there in the elimination of up to three mice from every test system.

The acquisition cost of an SI or SMS system is an interesting question. On the basis of a single function, we will generally pay more for the synthetic solution at this time. As we add functions, SI becomes much more attractive in general. Cost comparisons are very dangerous in the abstract, so these comments, and ***Table 1***, should be taken with a grain of salt. But the generality today is that without the manufacturing volume, and in the particular the case of VXI, the need for a mainframe adds significant cost unless it can be amortized across several functions. This situation may change in the future as the balance of manufacturing volumes changes between traditional instruments and the various SI approaches.

DEVICE MODELING AS A DEMONSTRATION OF THE FLEXIBILITY OF SI

Our experience with the capabilities of both traditional and SI approaches can be illustrated by a real world situation. Developing state-of-the-art device models for the PHEMT market entails some unique test requirements. To develop these models we require a VNA that is capable of short pulse operation, sometimes as short as several hundred nanoseconds. A typical test configuration is shown in ***Figure 6*** with the short pulse VNA, SA, DC pulse modulation capability. Finally, to frost this cake, we layer on the requirement of large-signal load-pull capability to verify the resulting model.

The full range of measurements required here cannot be achieved by current commercial instrumentation. In particular, low duty cycle short pulse operation, to control thermal and trapping effects, leads to unacceptably long test times. A typical measurement suite may require approximately 200 bias point measurements to characterize a device. These measurements on commercial instrumentation would take weeks. By parsing the test system



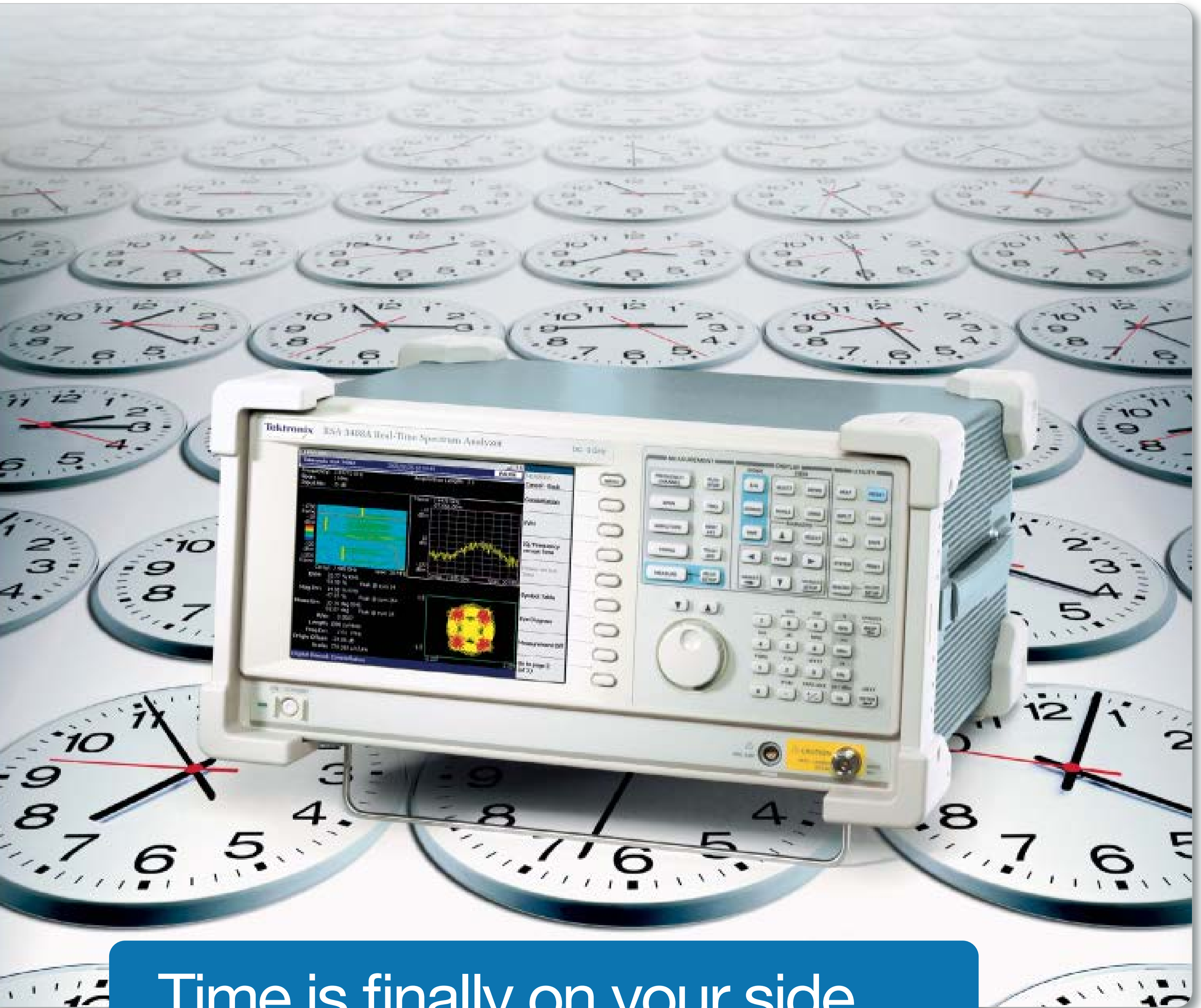
▲ *Fig. 6 Typical DC/RF and load-pull system block diagram.*

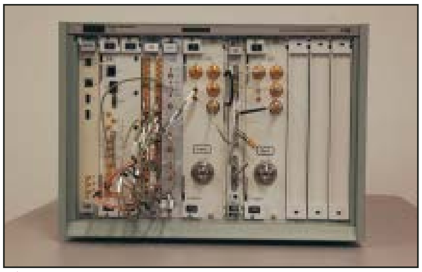
and implementing as an SMS system, we have driven this measurement time to approximately eight hours.

WHAT ARE THE MARKETS FOR SI/SMS

So what markets are the SI and SMS approaches focused on? Clearly aerospace and defense are addressed by the stability and longevity of VXI and LXI. We can grant LXI these characteristics as it is based on well-established standards in both the physical characteristics, 19" rack mount and in its communications as they are based on Ethernet, which has been around now for 40 years. PXI, being based and somewhat more dependent on computer hardware, runs the risk of being obsoleted by that market place. Manufacturing is an area in question. Typically, manufacturing places a premium on speed of test. With the exception of areas where SI performance can exceed traditional solutions, SI is not expected to offer speed advantages due to the required software, communications and triggering overheads involved with SI vs. traditional solutions.

SI and SMS solutions should be more compact than competing traditional solutions, PXI and VXI have already demonstrated significant space savings and ***Figure 7*** shows a standard C-size VXI-based SI VNA/SA demonstrating the reduction in space possible. This VXI mainframe, which is approximately 14 inches high, contains essentially all of the instrumentation to implement an SI VNA, SA, NFA and pulse power meter, which combined would require 25 inches of rack space, a 44 percent reduction.





▲ *Fig. 7 A standard C-size VXI-based SI VNA/SA.*

CONCLUSION

The most important feature of SI and SMS will be the ability moving forward to update the capabilities of a test system without wholesale replacement of components. Modification of a front-end down converter can extend the frequency range of all instrument functions, while new, faster and higher bit A/D and D/A functions become available to extend our dynamic range. As more test systems become SI-based, we can expect both different groupings of functions as well as more granularity of function. Both of these developments will affect how we upgrade in the future to meet new needs.

A brief summary of the main advantages of SI as a function of market space includes:

- Aerospace and Defense
  - Re-configurability supports long productive lifespan
  - Solutions potentially more compact than traditional solutions
- Research and Development
  - Peaked performance around specific performance characteristics
- Manufacturing
  - Just enough test
  - Potentially more compact
  - Rapid re-configurability

We discussed some of the cost, capability, and space and performance comparisons of SI vs. traditional instruments. Each implementation must clearly consider all aspects of the various technologies before a final solution is chosen. Fortunately, the well-designed specifications for all of the approaches we have considered here will allow us to co-mingle and intermix solutions, with minimal impact on overall system performance. ■

David Menzer *received his BS and MS degrees from Rensselaer Polytechnic Institute in 1975 and 1976, respectively. He is currently president and chief operating officer of Auriga Measurement Systems LLC. Prior to forming Auriga, he was director of business development for ACCO-USA. There, he oversaw the development and execution of sales programs, corporate and product marketing, and identified and developed new business opportunities. In support of international sales, he cultivated and supported three sales representative organizations in Europe and Asia. During his tenure, two major products were introduced, and over 10 major proposals were written, resulting in three contracts and five proposals in negotiation. A number of brochures and data sheets were also published under his direction.*

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LAVI-9VH+	820-870	990-1040	120-220	+19	+36	+23	7.2	46	46	15.95
LAVI-10VH+	300-1000	525-1175	60-875	+21	+33	+20	6.3	50	45	22.95
LAVI-17VH+	470-1730	600-1800	70-1000	+21	+32	+20	6.8	52	50	22.95
LAVI-22VH+	425-2200	525-2400	100-700	+21	+31	+20	7.7	50	45	24.95
LAVI-2VH+	2-1100	2-1100	2-1000	+23	+34	+23	7.5	48	47	24.95
LAVI-25VH+	400-2500	650-2800	70-1500	+23	+32	+20	7.5	50	45	24.95

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LOW NOISE OCTAVE BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
CA01-2110	0.5 - 1.0	28	1.0 MAX, 0.7 TYP	+10	+20	2.0:1
CA12-2110	1.0 - 2.0	30	1.0 MAX, 0.7 TYP	+10	+20	2.0:1
CA24-2110	2.0 - 4.0	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA48-2110	4.0 - 8.0	32	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA812-3110	8.0 - 12.0	27	1.8 MAX, 1.6 TYP	+10	+20	2.0:1
CA1218-4110	12.0 - 18.0	25	2.0 MAX, 1.8 TYP	+10	+20	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
CA0102-3110	0.1 - 2.0	28	2.0 Max, 1.5 Typ	+10	+20	2.0:1
CA0106-3110	0.1 - 6.0	28	2.0 Max, 1.5 Typ	+10	+20	2.0:1
CA0108-3110	0.1 - 8.0	26	2.2 Max, 1.8 Typ	+10	+20	2.0:1
CA0108-4112	0.1 - 8.0	32	3.0 MAX, 1.8 Typ	+22	+32	2.0:1
CA26-3110	2.0 - 6.0	26	2.0 MAX, 1.5 TYP	+10	+20	2.0:1
CA26-3113	2.0 - 6.0	28	4.0 MAX, 3.0 TYP	+27	+37	2.0:1
CA26-4114	2.0 - 6.0	22	5.0 MAX, 3.5 TYP	+30	+40	2.0:1
CA618-4112	6.0 - 18.0	25	5.0 MAX, 3.5 TYP	+23	+33	2.0:1
CA618-5113	6.0 - 18.0	24	5.0 MAX, 3.5 TYP	+27	+37	2.0:1
CA618-6114	6.0 - 18.0	35	5.0 MAX, 3.5 TYP	+30	+40	2.0:1
CA618-6115	6.0 - 18.0	35	6.0 MAX, 3.5 TYP	+32	+41	2.0:1
CA218-4110	2.0 - 18.0	30	5.0 MAX, 3.5 TYP	+20	+30	2.0:1
CA218-4112	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+24	+34	2.0:1
CA218-4113	2.0 - 18.0	29	5.0 MAX, 3.5 TYP	+27	+37	2.0:1

NARROW BAND AMPLIFIERS

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	3rd Order ICP dBm TYP	VSWR MAX
LOW NOISE:						
CA01-2110	0.4 - 0.5	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA01-2112	0.8 - 1.0	28	0.75 MAX, 0.45 TYP	+10	+20	2.0:1
CA12-3116	1.2 - 1.6	25	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.2 - 2.4	30	0.75 MAX, 0.5 TYP	+10	+20	2.0:1
CA23-3110	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10	+20	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10	+20	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10	+20	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10	+20	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.5 TYP	+10	+20	2.0:1
CA1819-4110	17.7 - 18.3	20	2.0 MAX, 1.8 TYP	+10	+20	2.0:1
MEDIUM POWER:						
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA23-4110	2.7 - 2.9	32	4.0 MAX, 3.0 TYP	+33	+41	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35	+43	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33	+41	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33	+42	2.0:1
CA1218-5116	12.0 - 18.0	35	6.0 MAX, 5.0 TYP	+30	+40	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30	+40	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21	+31	2.0:1
CA1718-4110	17.7 - 18.1	25	5.0 MAX, 4.5 TYP	+27	+37	2.0:1

COMPETITIVE PRICING OFFERED

Model No.	Frequency GHz	Gain dB MIN	Noise Figure dB	Output Power (dBm) MIN @ P1 dB Comp PT	Unit Price Qty 1-9 $US
CA12-A02	1.0-2.0	26	1.6	+10	$395
CA24-A02	2.0-4.0	26	1.8	+10	$395
CA48-A02	4.0-8.0	24	2.0	+10	$395
CA812-A02	8.0-12.0	22	2.5	+10	$395
CA1218-A02	12.0-18.0	16	3.5	+10	$395

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First Flight Tests of Airborne Networking System Complete

Northrop Grumman Corp. and the US Air Force successfully completed flight testing of the Battlefield Airborne Communications Node (BACN), a significant milestone toward providing warfighters an advanced way to share critical information by communicating over airborne networks at high altitudes. BACN is an Internet protocol-based airborne communications relay and information server that links radios and intelligence, surveillance and reconnaissance systems for the US Department of Defense networks. Flying at extremely high altitude, BACN extends the range of line-of-sight radios, relaying information to airborne and surface-based units and, via satellite, to distant command centers. For the flight tests, conducted earlier at US Marine Corps Air Station Miramar in San Diego, CA, the BACN gateway system payload was carried by a NASA WB-57 aircraft, selected because of its high altitude flight capabilities. The tests included radio communications between the airborne and ground systems and confirmed the communications capabilities required of the BACN system. BACN's forward-edge tactical server provides real time information access to situation awareness, surveillance, imagery and network management information for air and ground-based units, including the US Joint Forces Command's Rapid Attack Information Dissemination-Execution Relay mobile vehicle. The airborne executive processor assembles and manages ad-hoc Internet-protocol networks and bridges heterogeneous tactical data and voice networks. It is remotely controlled from ground units such as the Joint Interface Control Officer (JICO) Support System, the US military next-generation of joint and coalition network management systems also being developed by Northrop Grumman. "BACN provides the foundation for airborne networking," said Mike Twyman, vice president of Northrop Grumman Mission Systems' communications and information systems business unit. "After Joint Expeditionary Force Experiment 2006 (JEFX 06), we will work with the services to transition the capability to joint platforms including Global Hawk." In partnership with NASA's Johnson Space Center, Northrop Grumman developed an economical way to demonstrate BACN's capabilities by first flying it aboard the NASA WB-57 as a surrogate for the Air Force RQ-4 Global Hawk unmanned aerial vehicle. The WB-57, with its 2000 square-foot wing, was the only aircraft available that could sustain flight at more than 60,000 feet for more than four hours, fly flight profiles compatible with advanced Air Force fighter and bomber aircraft, and eliminate antenna co-site interference. Following initial flight testing from Miramar, the BACN system will be evaluated at the JEFX 06 exercise in April. During the JEFX 06, BACN will provide a fused operational picture to commanders at all levels and enable them to direct aircraft and forward deployed troops in real time. The Northrop Grumman team developed BACN for the US Air Force Electronic Systems Center at Hanscom Air Force Base, MA, and the Air Force Aerospace Command and Control and Intelligence, Surveillance and Reconnaissance Center at Langley Air Force Base, VA.

Air-to-Surface Missile Successfully Fired from Rotary Wing Aircraft

A Raytheon Co. Precision Attack Air-to-Surface Missile (PAASM) was successfully launched from a rotary-winged, unmanned aerial vehicle (UH-1) at White Sands Missile Range, NM. The missile was fired from a standard M299 digital launcher and met planned test objectives. Upon receiving the launch command, the PAASM missile successfully ignited and separated from the M299 launcher and transitioned into stable flight. The demonstration validated the capability of the Raytheon team to configure and integrate the missile system onto a standard, digital, single rail M299 launcher and satisfy standoff range and environmental requirements for a helicopter/UAV extended range, precision air-to-surface missile. "The Raytheon demonstration was a significant milestone for the team as PAASM provides an alternative, low cost missile solution to existing joint, extended range, rotary wing precision strike requirements," said Ken Pedersen, Raytheon Missile Systems vice president, Advanced Programs. "Additionally, Apache Block 2/3, ARH, AH-1Z, Warrior, Predator B and Future Combat System's Unmanned Aerial Systems will all be 'net-enabled' platforms and will be able to fully utilize the networked capability of PAASM." PAASM is a joint, multi-platform, precision strike missile designed to engage and destroy stationary, re-locatable and moving targets ranging from buildings and bunkers to tactical vehicles and advanced armor. The weapon is also optimized to fight in today's urban and complex terrain environment and destroy naval targets such as patrol craft. PAASM could be available in production as early as 2009 to support modern tri-service rotary wing, UAV and special operation platforms.

Guided MLRS Unitary Rocket Successfully Tested

Lockheed Martin successfully conducted three flight tests of the Guided Multiple Launch Rocket System (GMLRS) Unitary rockets recently in three separate missions at White Sands Missile Range, NM. The tests objectives included demonstrating the GMLRS Unitary rocket in the point detonate, delay and proximity modes at short and long range. The GMLRS Unitary warhead has a tri-mode fuze, which allows airburst, point-impact and delay detonation modes. These missions were part of the production qualification test (PQT) flight test series of the GMLRS Unitary Rocket, which is manufactured at Lockheed Martin's Camden, AR, facility. "These missions were production qualification, man-in-the-cab launches of the GMLRS Unitary rocket, and all three flights met our expectations for extreme accuracy," said Al Duchesne, director – MLRS Rocket Programs at Lockheed Martin Missile and Fire Control. "These tests demonstrated the capability of the GMLRS Unitary Rocket against tactical targets, collecting valuable information for its use on the battlefield." Lockheed Martin received a $119 M contract to conduct System Development and Demonstration (SDD) for a GMLRS variant, with a single warhead in October 2003. The SDD contract includes 86 rockets, 71 of which are flight articles, with the balance supporting test and other activities. The contract also provides test hardware to support 26 flight tests for an initial configuration and 39 flight tests of a follow-on configuration. The SDD phase of this program was preceded by a successful system demonstration in 2002 of a Quick Reaction Unitary Rocket and a nine-month Component Advanced Development program. The Guided Unitary SDD program will continue through 2007. Lockheed Martin received a $12.5 M contract in early 2005 to accelerate the GMLRS Unitary rocket program for the US Army. This represents a modification to the existing SDD contract, and accelerates the completion of the test program by 21 months. Lockheed Martin completed delivery of the first 72 GMLRS Unitary rockets in June 2005, satisfying the requirements of the Urgent Need Statement requested by the US Army Aviation and Missile Command (AMCOM), Redstone Arsenal, AL. A total of 498 rockets will be delivered according to the UNS. "Basically, it [GMLRS Unitary] is a safer munition for our troops and nearby civilians, but a more deadly munition for the insurgents," said Sgt. 1st class Paul Luketich, senior fire control non-commissioned officer, Force Field Artillery Headquarters (FFA HQ), Multinational Corps-Iraq (MNC-I). "It is the best munition in the arsenal today." According to Duchesne, "Guided Unitary is proving to be one of the most highly effective munitions in our troops' arsenal in theater. Not only does it limit collateral damage, but we are hearing that it has been extremely effective in the war on terror. It is so precise, it is providing a much quicker and more effective cover in those defining moments." Guided MLRS Unitary integrates a 180 lb unitary warhead into the GMLRS rocket, giving battlefield commanders the ability to attack targets up to 70 km away with high precision. This low cost, low risk program will greatly reduce collateral damage by providing enhanced accuracy to ensure delivery of the warhead to the target. ■

STMicroelectronics CLEANs up in Leadership Contest

STMicroelectronics has been given a leadership role in a new European Integrated Project – Controlling Leakage Power in NanoCMOS SoCs (CLEAN). The three-year research project, co-funded by the European Commission, aims to extend battery life and reduce the power consumed by electronics by finding solutions to controlling leakage currents in CMOS designs below 65 nm.

Within the CLEAN project, ST will manage and coordinate all of the activities of a consortium of 14 European partners, which cover a varied cross-section of the discipline (semiconductor vendors, EDA vendors, and renowned academic and research institutes), together with the appropriate mobilization of resources to guarantee the successful achievement of all of the project objectives.

The project's results are expected to span different aspects of low leakage design, from modeling to optimization, from design solutions to design methods and tools. Thanks to the competence mix of the project partners, encouraged by the European Commission, CLEAN's results are expected to provide great business opportunities for the advancements of the European nanoelectronics industry in different business sectors.

Romanian R&D Centre for Infineon

Aimed at expanding Infineon Technologies' presence in Eastern Europe and aid the research into power semiconductors and chip-card security controllers, the company has opened its newest development centre in Bucharest, Romania. The activities in the facility are being managed by the regional company, Infineon Technologies Romania SRL. The initial staff of approximately 60 developers will concentrate on power semiconductors with analogue and digital functions (power mixed signals), which are being used increasingly in automotive and industrial applications, and on security controllers for chip cards.

The new centre strengthens the research alliance in the area of intelligent power semiconductors, which currently includes the facilities in Villach (Austria), Padua (Italy), Munich (Germany) and Graz (Austria). The developmental activities being performed in Bucharest in the area of security controllers for chip cards are integrated into the research alliance with the established centres in Munich and Graz.

To support and encourage local talent, master-level programmes of study are being developed in conjunction with the University Politehnica of Bucharest, in order to form the educational structures needed to meet future R&D requirements in the semiconductor industry at an early stage. Also, during the course of 2006, about 60 additional developers are to be hired in Bucharest.

Western European Cellular Market to Slow

Cellular operators in Western Europe should expect another challenging year in 2006, according to *Western European Cellular User Forecasts, 2005–2010*, the latest research report on the subject from the Strategy Analytics Wireless Network Strategies service. Competitive pressure saw average revenues weaken in 2005 with churn creeping up and the report predicts no relief at all in 2006, though 3G growth is highlighted as one bright spot for the industry.

After growth in 2003 and 2004, average revenues per active subscriber fell one percent in 2005 and are forecast to fall two percent in 2006. 2005 was also the first year to witness a single-digit service revenue growth in the history of the Western European cellular market and it is forecast to grow by less than four percent in 2006.

In the Nordic region average revenues fell 11 percent in Finland in 2005, six percent in Norway and five percent in Sweden, while following market consolidation in Denmark, revenues grew there by three percent. Consequently, Nordic operators are keen investors in the wireless markets of Eastern Europe and beyond.

However, the silver lining is in the 3G market. WCDMA subscriber numbers quadrupled in 2005 in Western Europe to reach 25 million and they will more than double in 2006. Vodafone made strong inroads into Hutchison's 3G lead and has done much to raise the profile of 3G in the consumer space. It is expected that there will be over 100 million WCDMA users in Western Europe by the end of 2007.

Danish Defence Development at the Double

Denmark's two leading companies within the country's defence industry — Terma and Systematic — have concluded an agreement that will open up the prospects for export and enable the two companies to jointly bid for contracts which are expected from the Danish Army. With the Danish market as the platform, the partners aim to offer their competencies for solving the major transformation tasks that the armed forces are currently facing both nationally and internationally. This mix of competencies is well established following the companies' recent close collaboration to co-develop and successfully implement an ultramodern Command and Control system for the Danish Navy.

For the latest agreement, the partners' main task will be to meet the challenge presented to the armed forces by Network Based Operations (NBO) involving the implementation of a major change process that facilitates communication across nations' armed forces and between various services and units within the armed forces. Both Terma and Systematic have substantial and complementary competencies within this area, thus presenting them with the opportunity of offering the Danish armed forces an outstanding solution within NBO.

Key Role for EADS SPACE in Galileo Test Phase

EADS SPACE is set to play a central role in the test phase for the new European satellite navigation system Galileo, following the signing of a contract between Galileo Industries, as the prime contractor, and the European Space Agency (ESA). The contract is worth €1 B with almost one fifth to be handled by the space units of EADS. The contract covers the development and construction of the first four Galileo constellation satellites and part of the ground infrastructure for Galileo, including the full testing of the subsystem.

The In Orbit Validation (IOV) phase is designed to test the new European satellite navigation system under real mission conditions. During this phase, EADS Astrium in Ottobrunn, Germany, will assume system leadership for the space segment and initially take overall responsibility for the construction of the first four of 30 satellites. In Ottobrunn, important components such as the attitude control system will be designed and manufactured. In conjunction with Dutch Space, the company will also provide the solar arrays for the four satellites, while the propulsion units will come from EADS SPACE Transportation in Lampoldshausen, Germany.

Responsibility for the payload on board the four satellites and also the ground control segment, which provides satellite control, lies with EADS Astrium in the United Kingdom. EADS Astrium in Portsmouth, UK, will assume system responsibility for the globally deployed ground control segment covering the 30 satellite constellations in orbit. In addition, Portsmouth will design and manufacture the onboard navigation payload, which generates and transmits the navigation signals to users, and also important equipment such as the solid-state power amplifiers.

EADS SPACE in France and Spain will also contribute to the IOV phase. The French facility is involved in the ground mission segment, while the Spanish companies will contribute the navigation antennas as well as have involvement in the space segment system engineering. ■

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ZX95-100	50-100	10.0	-110	17	-33	20	37.95
ZX95-200	100-200	10.0	-106	17	-30	20	37.95
ZX95-400	200-380	10.0	-104	17	-25	21	39.95
ZX95-535	300-520	6.0	-101	17	-25	21	39.95
ZX95-765	485-765	8.0	-98	16	-35	22	40.95
ZX95-1200W	612-1200	10.0	-96	18	-16	30	49.95
ZX95-1410	850-1410	8.0	-101	11	-17	30	44.95
ZX95-1600W	800-1600	9.0	-99	24	-22	35	44.95
ZX95-1700W	770-1700	9.0	-100	24	-25	35	49.95
ZX95-1900V	1450-1900	8.0	-104	20	-20	25	42.95
ZX95-2150VW	970-2150	4.0	-99	25	-22	26	54.95
ZX95-2500	1600-2500	7.5	-91	14	-17	28	46.95
ZX95-2650	2165-2650	5.0	-101	19	-12	25	43.95

*Phase Noise: SSB at 10kHz offset, dBc/Hz.

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DAT SELECTION GUIDE

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Model Series	Interface	Z (Ω)	Freq. MHz	Atten. dB	Steps dB	Bits	Price $ea. (Qty.10)
DAT-15R5-P ▲	Parallel	50	DC-4000	15.5	0.5	5	3.55
DAT-15R5-S ▲	Serial	50	DC-4000	15.5	0.5	5	3.55
DAT-15575-P ▲	Parallel	75	DC-2000	15.5	0.5	5	3.55
DAT-15575-S ▲	Serial	75	DC-2000	15.5	0.5	5	3.55
DAT-31-P ▲	Parallel	50	DC-2400	31.0	1.0	5	3.55
DAT-31-S ▲	Serial	50	DC-2400	31.0	1.0	5	3.55
DAT-3175-P ▲	Parallel	75	DC-2000	31.0	1.0	5	3.55
DAT-3175-S ▲	Serial	75	DC-2000	31.0	1.0	5	3.55
DAT-31R5-P ▲	Parallel	50	DC-2400	31.5	0.5	6	3.80
DAT-31R5-S ▲	Serial	50	DC-2400	31.5	0.5	6	3.80
DAT-31575-P ▲	Parallel	75	DC-2000	31.5	0.5	6	3.80
DAT-31575-S ▲	Serial	75	DC-2000	31.5	0.5	6	3.80

▲To specify Supply Voltage:
Add the letter (P) to model number for positive +3 volts.
Add the letter (N) to model number for Dual ±3 volts.

Example: DAT-15R5-PP or DAT-15R5-PN

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Explosive Growth Projected for RFID Tags

Over 1.3 billion radio frequency identification (RFID) tags were produced in 2005 and, by 2010, that figure will soar to 33 billion, reports In-Stat. However, production will vary widely by industry segment for several years. For example, RFID has been used in automotive keys since 1991, with 150 million units now in use. This quantity greatly exceeded other segments until recently. "By far the biggest RFID segment in coming years will be Supply Chain Management," says Allen Nogee, In-Stat analyst. "This segment will account for the largest number of tags/labels from 2005 through 2010. Wal-Mart, the world's largest retailer, has spurred this projected growth by mandating that its top 100 (and, later its top 300) suppliers begin to use RFID."

A recent report by In-Stat found the following:

- The spread and use of RFID in most sectors will be largely determined by cost and the cost of RFID tags and labels are dropping quickly.
- Pharmaceutical companies are investigating using RFID tags to reduce counterfeiting and black market sales.
- Privacy issues have been raised concerning many uses of RFID, and currently courts and governments around the world are in the process of determining related legal issues.

The report, "RFID Tags and Chips: Opportunities in the Second Generation," contains estimates and five-year forecasts of the number of tags produced and revenue earned from tag sales, broken down into the following segments: livestock, domestic pets, humans, carton/supply chain uses, pharmaceuticals, large freight containers, package tracking, consumer products, security/banking/purchasing/access control and others.

UWB Standardization Collapses; Conflict Moves to the Market

On January 19, 2006, the 802.15.3a task group was officially disbanded after a stunning 94.7 percent vote in favor of the break-up. Ironically, this represents probably the only time there has been a consensus in the working group for at least two years. Although this outcome was in the cards with predictions of disbandment coming from notable sources such as Edward Thomas, former chief engineer of the FCC, the reality is still a hard pill to swallow. Who will win out? It seems likely that the UWB community has shot itself in the foot over IP. With neither camp willing to compromise — even with the introduction of a solution by Pulse~LINK that would support both PHYs — the battle for supremacy has relocated to the market. The WiMedia alliance points to its multiple silicon sources as a major plus point and in doing so pours scorn on the single-source for DS-UWB, which was referred to as a proprietary solution recently by Jim Lansford, CTO of Alereon. The Freescale-backed UWB forum points to the fact that products are already in the market as a key indicator of its technology's proven readiness, while also insinuating a weakness in the WiMedia proposition arising from its lack of products. The situation is very reminiscent of the VHS versus Betamax equation, in that it is no longer about the technical suitability and proficiency of any technology, but about market traction, momentum and backing. This is not a cut-and-dried battle for market share, though. It is virgin territory and there is no guarantee that lack of standardization will not result in competition from other technologies and regulatory bodies' reluctance to approve a non-standardized technology, significantly reducing the final size of the pie that each camp is so bent on seizing. These and many other issues are covered in ABI Research's "Short Range Wireless Research Service," that provides highly relevant, timely and comprehensive research on Bluetooth, NFC, Zigbee, DSRC and UWB markets.

WiMAX Getting Real, but What About 802.20?

With the recent announcement from the WiMAX Forum that some companies equipment has successfully passed the "first wave" of WiMAX certification for 802.16-2004, WiMAX is finally starting to get real. Aperto Networks' PacketMAX 5000 base station, Redline Communications' RedMAX AN-100U base station, SEQUANS Communications' SQN base station solution and Wavesat's miniMAX customer premise equipment (CPE) solution are all now certified as "first wave" approved. "This is a major milestone," according to ABI Research's senior analyst of wireless connectivity research, Philip Solis. "There is a long queue of companies waiting to undergo the same certification process. Then they can proceed to 'wave 2,' covering security and quality-of-service, and when they too are certified, we can expect to see larger numbers of products actually reaching the market." At that stage, the market will begin to widen and there will be real interest from wireless ISPs in deploying certified WiMAX solutions rather than the proprietary systems that have been available for some time. In fact, several initial deployments of pre-WiMAX networks are under way across the globe, including a growing number from Latin America. The picture is complicated, however, by a resurgence of rival wireless broadband access technology 802.20, based on frequency-division duplex technology developed by Flarion. "With the closing of Qualcomm's acquisition of Flarion, 802.20 may get a new lease on life," notes Solis. "Qualcomm will almost certainly attempt to rally support from other industry participants, but many companies had abandoned 802.20 to support 802.16e."

Wireless Connectivity Found in 65 Percent of Networked Home Devices

According to the latest Strategy Analytics Connected Home Devices research, nearly two-thirds of available networked home devices are now integrated with, or upgradeable to, WiFi connectivity. The survey examined nearly 200 networked home devices from 74 manufacturers in the US, Europe and Japan, including leading consumer electronics brands such as Sony, Samsung, Panasonic, Philips, Sharp, Thomson and Toshiba; PC manufacturers like HP, Fujitsu-Siemens and Gateway; home networking specialists such as Linksys, D-Link, Buffalo and Netgear; and hi-fi specialists like Onkyo, Yamaha and Kenwood. Networked home devices allow customers to get access to their digital music, video and photos in different parts of the home. Popular applications include transferring digital photos from the PC to the TV, or listening to MP3s on a stereo system. "WiFi technology is a natural complement to content sharing in the digital home," notes Peter King, director for the Connected Home Devices Service. "Our survey suggests that 802.11b and g are the dominant standards so far. 802.11a has so far gained little traction and we expect 802.11n to drive the next adoption wave beginning in late 2006."

TI Purchase of Chipcon — A Sure Sign of Growing Momentum for ZigBee?

Texas Instruments announced its intention to purchase Chipcon, a leading developer of ZigBee technology, for $200 M. When considered in isolation, this would seem to have little impact on the future of the ZigBee market, but looking a little deeper, it clearly has far more undertones. This move would give a foothold in numerous established and emerging wireless connectivity solutions from WiFi to Bluetooth — and now ZigBee. More importantly, the announcement demonstrates that after a slow start, momentum is building behind the ZigBee standard, with TI joining the ranks of Freescale, Motorola, Samsung and Mitsubishi. The level of support clearly indicates that even with significant issues surrounding the slow time to market for products because of a lengthy standard ratification exercise, this technology will happen in a big way. "The ZigBee standard was ratified last December and ABI Research correctly predicted that the race to market would begin in earnest," stated principal analyst, Stuart Carlaw. "This purchase shows that the addition of another super heavyweight contender is really heating up the race." ■

INDUSTRY NEWS

■ **QUALCOMM Inc.** announced that the company has acquired **Berkana Wireless Inc.**, a Silicon Valley-based fabless semiconductor company. Berkana is a provider of complementary metal oxide semiconductor radio frequency integrated circuits to the wireless industry. The addition of Berkana's RF CMOS intellectual property, design portfolio and engineering resources, as well as its cellular systems expertise, reinforces QUALCOMM's position in the RFIC industry and will help the company continue to deliver CDMA2000® and WCDMA RF solutions to its customers and the growing number of 3G subscribers around the world.

■ **Analog Devices Inc.** (ADI) announced that it has signed a definitive agreement with **Ikanos Communications Inc.** to sell its FUSIV network processor and Asymmetrical Digital Subscriber Line (ADSL) application-specific integrated circuit (ASIC) product line. The divesture is in line with ADI's strategy of focusing its digital signal processing (DSP) investments in areas where ADI's signal processing expertise can earn good returns. This product line currently represents approximately 2 percent of revenue for ADI. The transaction is expected to be complete in the first calendar quarter of 2006 and result in the recognition of a small gain on the sale.

■ **Spirent Communications** announced that it has entered into an agreement to acquire **SwissQual**, a test and measurement company for wireless network operators. The company made the acquisition for a consideration totaling up to $70.5 M USD (including performance incentives) on a cash and debt-free basis. The acquisition of SwissQual will enhance Spirent's presence in the wireless test and measurement market by bringing exposure to a new segment, subscriber experience management.

■ **WiSpry Inc.**, a developer of low cost, high performance radio frequency microelectromechanical systems tunable components and modules, and **Jazz Semiconductor**, an independent wafer foundry focused on specialty complementary metal oxide semiconductor process technologies, announced that they have partnered to create innovative RF MEMS offerings using Jazz's RF CMOS processes. The program has successfully demonstrated the feasibility of commercially manufacturing WiSpry's digitally tunable capacitor devices into Jazz Semiconductor's 200 mm wafer fab and provides commercial availability of highly integrated RF MEMS devices, built upon Jazz's processes.

■ **TestMart** announced an agreement with **Graphtec America Inc.** The deal provides the US government and federal contractors a marketplace with special pricing on intelligent recording instruments and data acquisition systems.

■ **Emerson & Cuming Microwave Products HK Ltd.** has announced the opening of the company's Hong Kong operation. These expansion plans are expected to better position the company to increase its business presence in the Asia-Pacific region. The sales and administration office, managed by Brent Ng, is located at Unit 13, 23rd Floor, Seapower Tower, Concordia Plaza, No. 1 Science Museum Road, Tsim Sha Tsui East, Hong Kong +852 2620 6389, fax: +852 2620 6619 or e-mail: brent@hk.eccosorb.com. Customers can also find support via an information web site in Chinese at www.eccosorb.cn.

■ **Agilent Technologies Inc.** announced the availability of GENESYS 2005, a new release of its RF and microwave design software. The version includes a new time-domain simulator, frequency planner, mixer synthesis tool and revamped user interface that help speed circuit simulation and wireless communications design.

■ **StratEdge** announced that one of its DC to 23 GHz low cost commercial packages is used by **Accel-RF** as a platform for life testing of high frequency devices. Accel-RF, San Diego, CA, makes fully integrated, automated systems that characterize RF and DC performance degradation to predict device life expectancy.

■ Centro de Tecnología de las Comunicaciones S.A. (**CETECOM**), Spain, has been approved by the PCS Type Certification Review Board (PTCRB) as a PTCRB GERAN laboratory. With this approval, the company is able to offer conformance testing services for the two private certification schemes used in GSM and UMTS technologies, the Global Certification Forum (GCF) and the PCS Type Certification Review Board. Following this approval CETECOM Spain now covers 2G/3G, Bluetooth, WiFi, WiMAX testing and regulatory compliance services, and is a one-stop shop for manufacturers of next generation personal communication devices in the global market.

■ **RF Monolithics Inc.** announced that the **US Federal Communications Commission** (FCC) and the **European Telecommunications Standards Institute** (ETSI) have both certified the company's newly announced DM1800 embedded wireless mesh networking module. With this regulatory approval, the DM1800 is now available to provide connectivity in wireless sensor network applications in the United States and Europe.

■ **Symmetricom Inc.** announced the 20th anniversary of its active hydrogen maser MHM 2010,™ a commercially available active hydrogen maser that offers the highest in atomic frequency standard performance and reliability. The first commercially available maser shipped from Symmetricom in 1985, and since that time, 85 have been deployed throughout the world to institutions at the forefront of time and frequency excellence. The company also announced a new extended seven-year warranty for the maser.

■ **Amphenol RF** announced that it has signed a definitive agreement to join the Quick Lock Formula® Alliance. Amphenol RF signed a QMA and QN license agreement with Huber+Suhner AG and Radiall SA and soon will join the alliance. The QLF Alliance includes RF interconnect compa-

nies with certified intermateable QMA and QN connectors that are quick disconnect versions of the SMA and Type N connectors. Both offer a more convenient installation with its patented snap-on interface in place of a threaded coupling. Only QLF Alliance members can guarantee product intermateability between manufacturers. The members are Huber+Suhner AG, Radiall SA, Rosenberger Hochfrequenztechnik GmbH & Co. and Amphenol RF.

■ **Stealth Microwave** announced its continued membership in the WiMAX Forum, in support of the IEEE 802.16 standards utilized in next generation broadband wireless access equipment.

■ **Vishay Intertechnology Inc.** recently won an award from the French association **SPDEI**, which includes over 40 distributors of electronic components.

CONTRACTS

■ **Unity Wireless Corp.** announced that it has received a $1.2 M purchase order from a North American tier-one wireless equipment original equipment manufacturer (OEM). This is the first order that Unity Wireless has received under a recently announced master supply agreement with this customer.

■ **TECOM Industries Inc.** announced the award of an initial production contract for 50,000 endpoint antennas by a fixed network provider. This new contract award follows the completion of successful field trials of pre-production units delivered by TECOM in July 2005.

■ **Valpey Fisher**, a distributor and manufacturer of custom and standard frequency control products, announced it has been awarded a $250,000 design win from a leading provider of wireless fire detection systems for the company's low cost surface-mount voltage-controlled oscillators (VCO) line of products.

■ **AR Worldwide Modular RF** announced that it has been working on an amplifier system for **Akrion**, an ultrasonics systems company and its subsidiary, Goldfinger Technologies LLC. Akrion, which, along with Goldfinger, provides flexible, single-wafer and batch immersion wet processing solutions to customers worldwide, approached AR for help in replacing a field product that was about to be discontinued. AR was charged with developing the RF amplifier system while another company created the signal source and control system.

■ **Aeroflex** has announced that it won a significant order for its high speed downlink packet access (HSDPA) conformance test system for **Motorola**'s ADR Testing Service. Based in Flensburg, Germany, ADR Testing Service is an independent 2G/3G, Bluetooth and EMC certification laboratory. Aeroflex's 6401 AIME/CT with inter-system handover and HSDPA conformance test cases will provide the backbone of a comprehensive HSDPA testing capability that ADR Testing Service is establishing to maintain its position and keep its test laboratory at the forefront of the mobile handset testing industry.

■ **Applied Wave Research Inc.** (AWR) announced that in a recent competitive tool evaluation, **Andrew Corp.** selected AWR's Microwave Office® and Visual System SimulatorT products.

FINANCIAL NEWS

■ **Silicon Laboratories Inc.** reports sales of $110 M for the fourth quarter ended December 31, 2005, compared to $95 M for the same period in 2004. Net income for the quarter was $15 M ($0.27/per diluted share), compared to a net income of $13 M ($0.24/per diluted share) for the fourth quarter of last year.

PERSONNEL

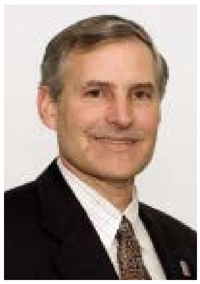
■ WJ Communications Inc. announced the appointment of **Herald Y. Chen** to its board of directors, effective immediately. The company also announced that Jan Loeber has resigned from his position as a member of the board of directors of WJ for personal reasons. Chen is currently a managing director of Fox Paine and Co. LLC, a US private equity firm based in the San Francisco area, where he also served as CEO of ACMI Corp., a former Fox Paine portfolio company.


▲ Arthur Buckland

■ Richardson Electronics Ltd. announced the appointment of **Arthur Buckland** to president, chief operating officer and board member. Bruce Johnson, former president and chief operating officer, has retired, but will continue as President Emeritus and director of Richardson. Prior to joining Richardson Electronics, Buckland was awarded the "Entrepreneur of the Year" from NASDAQ, E&Y and others for his role as chairman, CEO and president of Clare Inc. from 1993 to 2001.

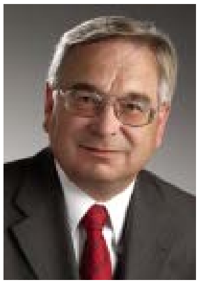

▲ Bruce W. Hueners

Palomar Technologies announced that **Bruce W. Hueners** has been named company president. Hueners joined Palomar Technologies in 1981 when it was Hughes Aircraft and most recently held the position of COO.


▲ David Bender

■ Crane Co. has announced the appointment of **David Bender** as president of the electronics group of Crane Aerospace and Electronics. In this capacity, Bender is responsible for Electronics Group product and service solutions. He will be located in Redmond, WA. Before joining Crane Aerospace and Electronics, Bender served at Aerojet General Corp., a division of GenCorp, where his most recent role was vice president of operations.

■ Hittite Microwave Corp. announced the promotion of **Brian Jablonski** to vice president of operations. In this position, Jablonski is responsible for the company's supply chain management and manufacturing operations. Jablonski had served as director of operations of the company since 2004.


▲ Michael Vohrer

■ **Michael Vohrer** has assumed the mantle of president and CEO of Rohde & Schwarz, following the retirement of Friedrich Schwarz, who had been in the role for the past 10 years and a member of the Executive Board for 35 years. Vohrer became a member of the Executive Board himself in 2003 and has been with the company for 30 years. Prior to joining the Board he served as head of the Test and Measurement Division, during which time he greatly expanded the company's market share in this segment.


▲ Harvey Clough

■ Janos Technology Inc. announced the appointment of **Harvey Clough** as president. Prior to joining Janos Technology, Clough was the president and COO of Energy Sciences Inc.

■ Anritsu Co. president Frank Tiernan announced the promotion of **Don Bradley** to the position of senior fellow. During his 29-year tenure with Anritsu, Bradley has received more than 30 US and foreign patents, and has been instrumental in the conception and design of many of Anritsu Co.'s most successful products, including the Site Master™ family of handheld cable and antenna analyzers. Prior to joining Anritsu, Bradley worked for several other electronic firms, including California Microwave and Cushman Electronics.


▲ Mercedes Johnson

■ **Mercedes Johnson** has been appointed to the position of chief financial officer of Avago Technologies. She will have overall responsibility for the company's financial operations, including corporate finance and accounting, planning, tax, treasury, business development, investor relations, internal audit, risk management and information technology. Johnson most recently worked for Lam Research Corp., serving for seven years as senior vice president of finance and chief financial officer. Prior to that, she was employed for nearly 11 years with Applied Materials Inc., where she served in various senior financial management positions.

■ Interconnect Devices Inc. (IDI) announced the appointment of **Karen Bock** to vice president of marketing. Bock has been employed at IDI for 17 years. During that time she has served as quality control manager, application engineer and marketing communications manager.

■ **Marta Rencz**, head of the department of electron devices at the Technical University of Budapest and the CEO of MicReD Ltd., a **Flomerics Group** company, has been elected to the Board of Management of the EU-funded Network of Excellence, PATENT-DfMM as manager of the Modeling and Simulation work package. In this capacity she will serve as liaison between the board and the 16 university and industrial partners participating

in the simulation activities of the project. The NoE Patent-DfMM aims to establish a collaborative team to provide European industry with support in the field of Design for Micro and Nano Manufacture (DfMM) to ensure that problems affecting the manufacture and reliability of products based on micro nano technologies (MNT) can be addressed before prototype and pre-production.


▲ *Mason F. Fein*

■ **Mason F. Fein** has been appointed director of sales at Wide Band Systems Inc., Rockaway, NJ, according to an announcement by William B. Sullivan, president. His responsibilities will include worldwide sales of the company's miniature fast frequency synthesizers for automated test equipment, simulator systems, built-in-test equipment, local and digitally tuned oscillators, and other RF and microwave applications. Fein was most recently director of sales at Red Rock Technologies Inc., Scottsdale, AZ.

■ Renaissance Electronics Corp. announced the appointment of **Alex Sierra** as international sales manager for the Ferrite Product Group. Sierra, an aerospace engineering graduate from the University of Florida at Gainesville, has joined the company's sales team and will oversee the international efforts. He can be reached at (978) 772-7774 x15 or e-mail: asierra@rec-usa.com.

■ **Urs Alder**, corporate human resources manager and member of extended corporate management of Huber+Suhner, has joined the Executive Group Management. The move is designed to emphasize the strategic importance of human resources and recognizes the contribution of Alder to the company. A graduate of Harvard Business School's HR Management Program, he joined Huber+Suhner in 1991 and has headed human resources for the entire group since 2003. He started as a human resources section leader, and managed Human Resources Switzerland from 2001 to 2003.

REP APPOINTMENTS

■ **RFMW Ltd.** announced that it has signed a distribution agreement for the Americas with **EMC Technology Inc.**, a manufacturer of RF/microwave surface-mount terminations, attenuators and resistive products. RFMW is a specialized distributor that provides customers and suppliers with focused distribution of RF and microwave components as well as specialized component-engineering support.

■ **Trilithic**'s RF and Microwave Components division welcomes new companies to its representative team. These appointments will have exclusive technical representation in several regions. **dBD Communications Ltd.** will be responsible for sales and support in the United Kingdom. **GCS Electronics LLC** will handle the full line of Trilithic products in Maryland, Washington, DC and northern Virginia.

■ Roseville, CA-based **Vista RF Inc.**, a maker of low cost, high performance components for the telecommunications industry, announced that the company has signed a new

sales organization for France. **Atlanthys** will be responsible for marketing Vista RF's products and establishing new customer relationships with companies based in France. Customers can begin working directly with Atlanthys by contacting Laurent Rault, sales director, 02 96 29 43 44, fax: 02 96 29 43 45 or e-mail: atlanthys@atlanthys.com.

■ Giving design engineers of hybrid microelectronics expanded options and worldwide availability for ultra stable, tantalum nitride miniature resistor die, **TT electronics IRC Advanced Film Division** has added **Chip Supply Inc.** as a die distributor for its wire bondable chips. Located in Orlando, FL, Chip Supply has a facility comprised of two clean rooms and five buildings of processing space. Chip Supply will distribute IRC's WBC series product to all markets.

■ **CDM Electronics Inc.**, a distributor of commercial and military interconnect products, and provider of value-added contract manufacturing services, has announced an agreement with **J.A.T. Electronics**, a Canadian-based manufacturer's representative firm. The agreement is effective immediately, and authorizes the marketing, sales and support of all CDM's products and services throughout Canada.

■ **G.T. Microwave Inc.**, Randolph, NJ, announced the appointment of **Eltech Sales Associates** to cover New Jersey, Pennsylvania, New York City, Long Island and Orange, Rockland and Westchester counties of New York. Eltech Sales Associates can be contacted via e-mail at eltechrep@optonline.net. **Wes Tech Associates** will be responsible for coverage in Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Ohio and Wisconsin. Guy Cicinelli of Wes Tech Associates can be contacted via e-mail at guycicinelli@comcast.net.

■ **Networks International Corp.**, a provider of RF and microwave filters and assemblies, announced the appointment of **R&D Technologies** as its representative in Canada and **MHz Marketing** in Pennsylvania and southern New Jersey. You can reach R&D Technologies at david.rdt@rogers.com and MHz Marketing at www.mhzmidlantic.com.

■ **CAP Wireless Inc.**, a designer of RF and microwave amplifiers and amplifier subsystems, announced the appointment of **Imagitron Sales Co. Inc.** as its exclusive sales representative for Virginia, Maryland, Delaware, Pennsylvania, southern New Jersey and Washington, DC. Imagitron can be reached at 3321 Mt. Carmel Road, Upperco, MD 21155 (410) 374-5600. Additionally, CAP Wireless has appointed **RF Electronic Sales Co. Inc.** as its exclusive sales representative for metro New York and northern New Jersey. RF Electronic Sales can be reached at 366 North Broadway, Suite 410, Jericho, NY 11753 (516) 624-3800.

WEB SITE

■ **Vicor Corp.** announced the availability of Vicor Quality Center on www.vicorpower.com. This center is designed to satisfy the needs of customers or prospective customers for up-to-date information on quality operations at Vicor.

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- Single Supply: +5V @ 55 mA
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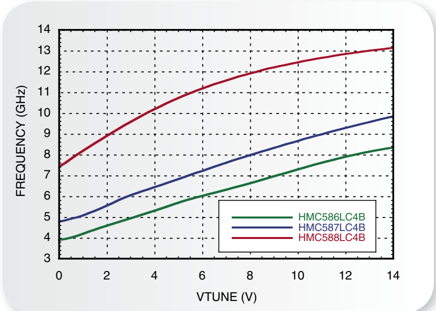
Frequency vs. Tuning Voltage



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- Low Phase Noise: -95 dBc/Hz @ 100 kHz Typ.
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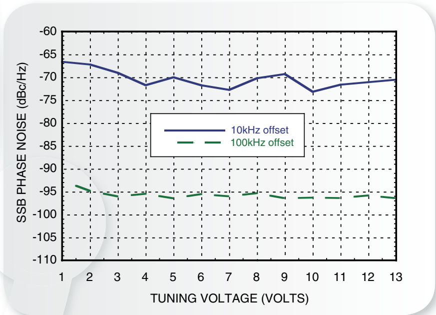
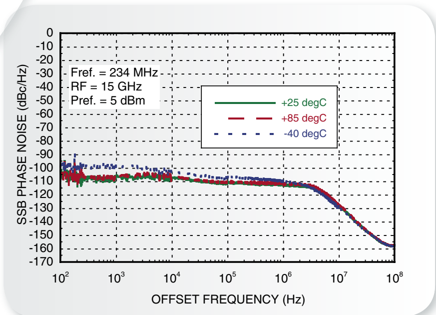
SSB Phase Noise vs. Tuning Voltage



Phase Locked Oscillator, 14.7 - 15.4 GHz

- HMC535LP4 (E)
- Pout: +9 dBm
- Low Phase Noise: -110 dBc/Hz @ 100 kHz Typ.
- RoHS Compliant 4x4 mm "E" SMT Package

Phase Noise Performance



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REAL-TIME SPECTRUM ANALYSIS STREAMLINES RADAR PULSE TESTING AND DIAGNOSTICS

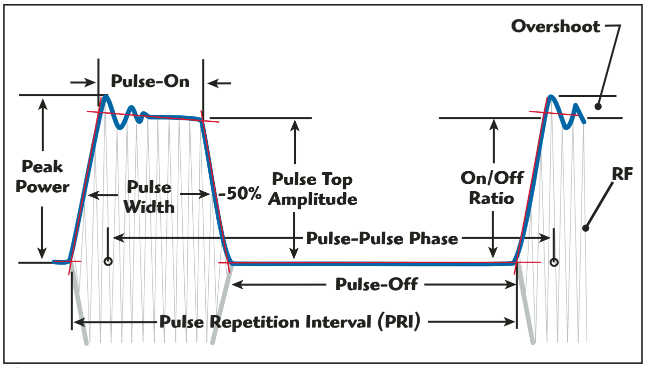
Whether imaging an asteroid at a range of 55 million miles (88 million km), guiding a strategic defense missile to its target with a monopulse tracking radar or launching a rocket propelled grenade in the blink of an eye as a counter-measure, it is easy to see how radar technology has progressed significantly in recent years. Today's advanced radars perform their amazing feats using intricate signals and advanced signal processing. Unfortunately, the complexity of modern radars can present significant test and diagnostic challenges.

Most radar systems transmit RF pulses and listen between transmissions for reflected signals. The shape, duty cycle and amplitude of the transmitted RF pulses determine important system parameters like detection range and minimum target resolution. To validate the system performance, analyses are required in both time domain, for shape and duty cycle, as well as in the frequency domain, for carrier frequency and bandwidth.

Complicating matters further, many radars use pulse compression techniques to improve range and resolution. By modulating the transmitted pulse, it is possible to separate received echoes that overlap in time and would not otherwise be resolved into individual targets. Initially, simple modulations such as an FM chirp (linear FM sweep) were used. Now, compression techniques also include a variety of phase modulations. Troubleshooting these modulated pulses presents additional test equipment demands. Compressed pulses require not only time and frequency analyses, but also modulation domain analysis. FM ramp linearity, bi-phase coding and many other modulation parameters become important metrics.

As if these test requirements were not enough, some sophisticated military radars must perform in complex spectral environments. Military radars are required to function correctly when subjected to a barrage of adjacent channel communications signals, disruptive noise jamming and intentionally deceptive jamming pulses. Capturing the intermittent radar pulse against a background of potential interferers demands outstanding RF triggering. This can be particularly difficult to accomplish under real-world operating conditions. Spectrally dense electronic warfare (EW) environments may contain jamming signals that are larger than the radar echo of interest. Triggering on the weaker intermittent radar pulse can present a tough problem for the test engineer.

MATTHEW J. MAXWELL
Tektronix Inc.
Beaverton, OR



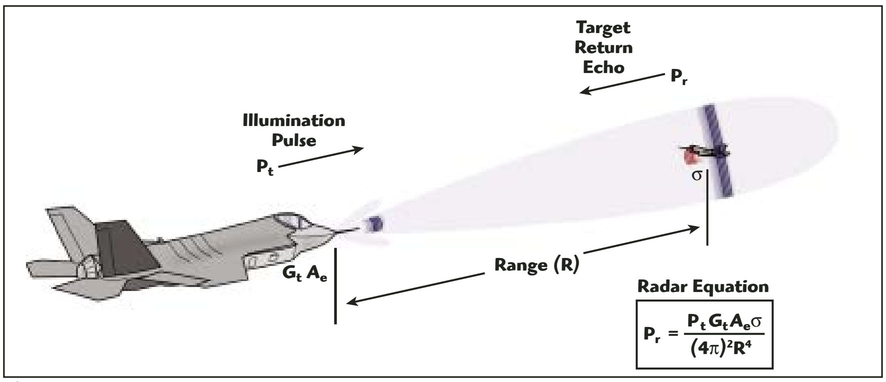
▲ *Fig. 1 Common radar pulse characteristics.*

PULSE CHARACTERISTICS AND THEIR EFFECT ON RADAR PERFORMANCE

Radars typically illuminate their targets with an RF pulse and then listen for the return echo. Since the RF pulse propagates at the speed of light, the time it takes for the echo to return is proportional to the distance between the source and the target. This, of course, applies to a primary-radar, one that relies on reflected energy bouncing back off the target. Secondary-radars that re-transmit the signal back from a transponder have additional delays.

The RF pulse characteristics determine a great deal about the radar's capability. EW and electronic intelligence (ELINT) experts specialize in the study of these pulsed signals. The pulse characteristics provide valuable information about the type of radar that sent the signal and what it might be attached to — a sailboat, battleship, passenger plane, bomber or missile, for example. The commonly used radar pulse characteristics are shown in ***Figure 1***. The pulse repetition interval (PRI) is the time the pulse cycle takes before repeating. It is equal to the reciprocal of the pulse repetition frequency (PRF) or pulse repetition rate (PRR), the number of transmitted pulses per second. PRI is important because it can limit the maximum unambiguous range or distance the radar can operate over. The pulse-off time may actually be a better indication of the radar system's maximum design range. Most radar systems employ a transmit/receive (T/R) switch to allow the transmitter and receiver to share a single antenna. The transmitter and receiver take turns using the antenna. The transmitter sends out pulses and during the off-time the receiver listens for the echo. The pulse-off time is the period the receiver can listen for the reflected echo. The longer the off-time, the farther away the target can be without the return delay putting the received pulse after the next transmitted pulse. This would incorrectly make the target appear to be reflected from a nearby object. To avoid this ambiguity, most radars simply use a pulse-off time that is long enough to make the echoes from a target at the farthest possible range to be still within the off-time and not overlap into the subsequent pulse's off-time.

Another consideration for the maximum range of the radar is the transmitted power. Peak power is a measure of the maximum instantaneous power level in the pulse. Power droop, pulse top amplitude and overshoot are also of interest. ELINT experts sometimes scrutinize these characteristics, as they can provide



▲ *Fig. 2 One form of the radar equation.*

additional information about the radar's qualities.

The pulse amplitude (power) and pulse width are important for calculating the total energy in a given pulse (power x time). Knowing the duty cycle, the ratio between the pulse width and the pulse repetition interval, and the power of a given pulse, the average RF power transmitted can be calculated (power x duty cycle). Unlike communications systems, radar systems suffer from very large signal path losses. The round trip distance is twice that of a communications link, and there are losses associated with the radar cross-section and the reflectivity of the target.

The radar equation shown in ***Figure 2*** relates the received power (P_r) to the transmitted pulse power (P_t), based on the antenna gain (G_t) and area (A_e), the target cross-section (σ) and the range distance (R). The range term is raised to the fourth power in the denominator, underscoring the tremendous losses the radar signal undergoes. There are several other forms of the radar equation that take into account differing applications and antenna configurations.

Using the radar equation, the received signal level can be calculated to determine if sufficient power exists to detect the radar pulse. Combining multiple pulses to accumulate greater signal power and average out the noise is also helpful for increasing the detection range. The pulse width is a particularly important radar signal property. The wider the pulse, the greater the energy contained within the pulse for a given amplitude. The greater the transmitted pulse power, the greater the reception range capability of the radar. A greater pulse width also increases the average transmitted power. This makes the transmitter work harder. The difference (in dB) between the average and the peak transmitted power levels is given by 10 times the logarithm of the duty cycle. The range is therefore limited by the pulse characteristics, the propagation losses and the target cross-section. The PRI and duty cycle set the maximum allowed time for a return echo, while the power or energy in the return signal must overcome the background noise at the receiver input.

The pulse width also affects the radar's minimum resolution, as shown in ***Figure 3***. Echoes from long pulses can overlap in time, making it impossible to determine the nature of the target or targets. A long transmitted pulse will produce a long received pulse. A long return pulse can result from a long transmit pulse if reflected from a single target or from the reflection of a tight formation of multiple targets composed of several long reflections that overlap. Without sufficient resolution, it is impossible to determine the number of objects that actually make up the echo return. A narrow pulse width avoids overlapping echoes and improves the resolution. Pulse width thus affects two very important radar system capabilities — resolution and detection range. Unfortunately, these two qualities are traded off against each other.

3 New Attenuators

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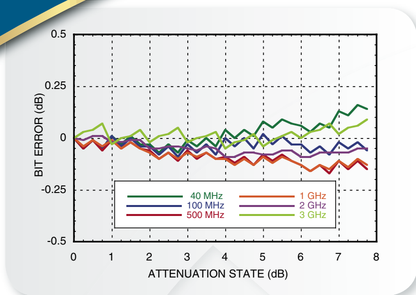
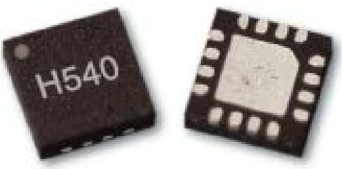
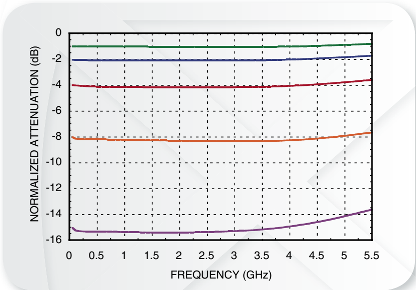


- 0.25 dB LSB Steps to 7.75 dB
- ±0.1 dB Accuracy
- Low Insertion Loss: 0.7 dB
- High IP3: +50 dBm

0.25 dB Steps!

HMC540LP3 (E) 4-Bit Digital Attenuator, DC - 5.5 GHz





- 1 dB LSB Steps to 15 dB
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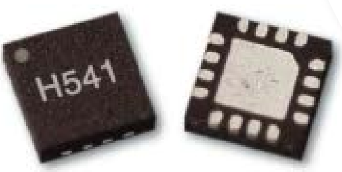

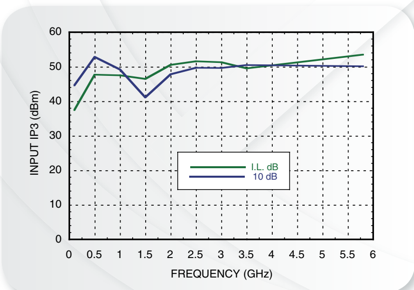

- Single 10 dB Step
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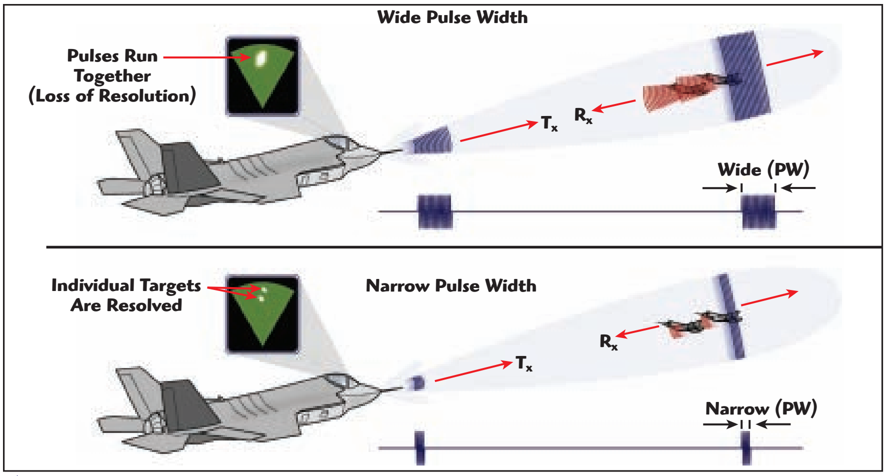


▲ *Fig. 3 Radar resolution.*

Wider pulses equate to longer-range radars with less resolution, whereas narrower pulses equate to finer resolution but shorter range. Narrow pulses also require greater bandwidth to be produced and received correctly. This makes the pulse's spectral nature another point of interest.

The time domain characteristics of the pulse naturally have their frequency domain equivalents. A narrow pulse width has a broader spectral shape than a wider pulse. Similarly, a higher pulse repetition frequency will have larger spaces between the spectral line components than a slow PRF.

PULSE RADAR TEST AND ANALYSIS APPROACHES

To truly understand the system performance and troubleshoot today's complex radar signals, the time, frequency and modulation domains all require analysis in a time-correlated fashion. Traditionally, no single test instrument was designed for this breadth of radar pulse analysis capability. Engineers have been forced to use many different test instruments in custom-built test sets to collect sufficient data for reliable troubleshooting. Unfortunately, using multiple test instruments is costly, time-consuming and can introduce measurement uncertainties that can lead to unreliable diagnostics.

Early radar diagnostics were performed primarily with an oscilloscope and RF diode detectors. The oscilloscope's limited frequency capability relegated its diagnostic applications to baseband waveforms (such as drive voltages to the magnetron tubes). In the 1960s, the swept spectrum analyzer became commercially available to the industry. This provided a convenient means to display the RF spectrum and determine if baseband pulse shapes were correctly translated to microwave frequencies. The swept analyzer's "Zero-span" (single-frequency operation using the selected bandwidth filter and sweeping the horizontal axis of the CRT in time, just like an oscilloscope) added another way to view the pulse amplitude versus time, and quickly replaced the much cruder diode detector. Employing both oscilloscopes and spectrum analyzers, time and frequency domain analysis of radar signals at baseband and RF was possible.

As pulse compression schemes grew in popularity, engineers needed a third test instrument — the analog modulation analyzer. This instrument provided a means to measure the linearity of the FM pulse compression (chirps). The modulation analyzer was later replaced by the more versatile vector signal analyzer (VSA), which could also analyze digital phase modulation. The VSA is not ideal for modulated pulse measurements, however, since it was initially developed for the continuous quadrature amplitude modulated (QAM) signals used in the telecommunications industry. VSAs typically have a rudimentary IF level-triggering ability unsuited for radar systems that must function in complex

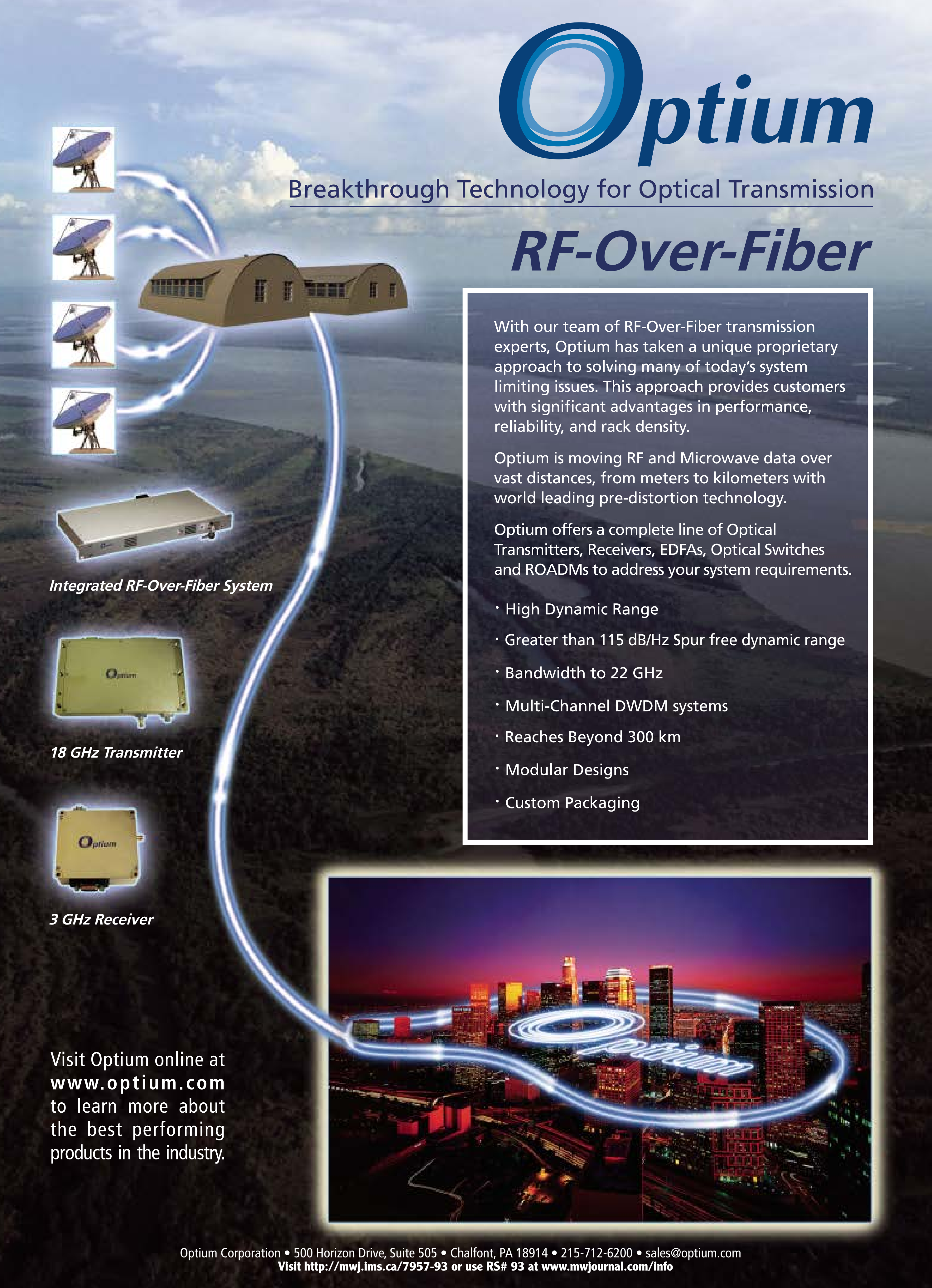
spectral environments. Even the latest VSAs lack comprehensive radar pulse analysis software, remaining focused on the consumer communications market. Until recently, this combination of oscilloscope, swept spectrum analyzer and VSA represented the mainstay of affordable, commercially available test equipment for the radar engineer. The only truly comprehensive multi-domain diagnostic solution available was the custom-built test set. Fortunately, the latest generation of real-time spectrum analyzers (RTSA) offers a cost-effective and efficient way to test and troubleshoot complex pulsed radar signals. They are able to trigger on an RF pulse, seamlessly capture it into memory and analyze the pulse in several time-correlated domains on a single instrument. Simplified block diagrams of these analyzers are shown in ***Figure 4***.

The RTSA was initially introduced at approximately the same time the VSA became popular and has always provided superior transient signal analysis capability relative to other test instruments. Its application to radar signal diagnostics was initially limited, however, as early RTSAs were rather expensive and used primarily for applications where national security issues warranted the high cost. As digital signal processing (DSP) technology has improved, the affordability of RTSA technology now falls within reach of even modest budgets and offers a viable alternative to the traditional custom-built test set for complex radars.

RTSA DELIVERS REAL-TIME TRIGGERING, SEAMLESS SIGNAL CAPTURE AND TIME-CORRELATED MULTI-DOMAIN ANALYSIS

The RTSA is fundamentally different in capability from the swept spectrum analyzer and VSA. Leading RTSAs are optimized to deliver real-time triggering, seamless signal capture and time-correlated multi-domain analysis. Their architecture and software are ideal for transient RF signals, including radar pulses. Unlike swept tuned analyzers and VSAs, the RTSA can process time domain data into the frequency domain in real-time. This allows the RTSA to continuously analyze its input spectrum by taking super fast, real-time fast Fourier transforms (FFT) of the input signal prior to triggering and capturing data. Conversely, other analyzers randomly capture the data or trigger on IF levels and then analyze what has been captured off-line, leaving large portions of the signal unanalyzed between sweeps or captures. The RTSA's ability to continuously analyze the signal and trigger to capture only on frequency events of interest is ideal for many radar applications.

Today's top RTSAs feature a unique frequency mask trigger (FMT), which can capture a spectrally interesting event, such as a weak radar pulse, under complex spectral conditions where other analyzers would fail. For example, a radar transmitter contains a large spurious CW leakage along with the desired pulses. This makes conventional IF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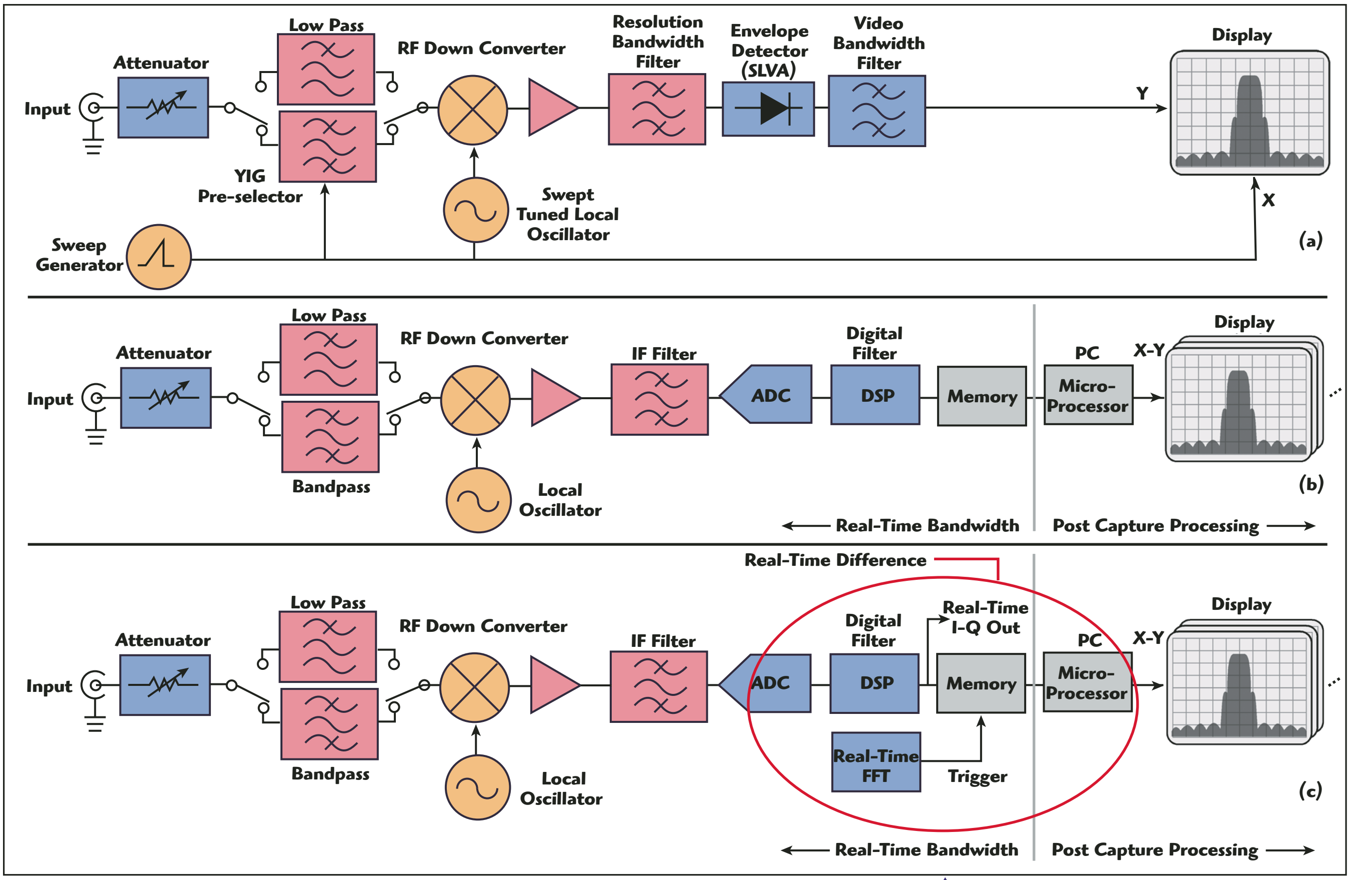
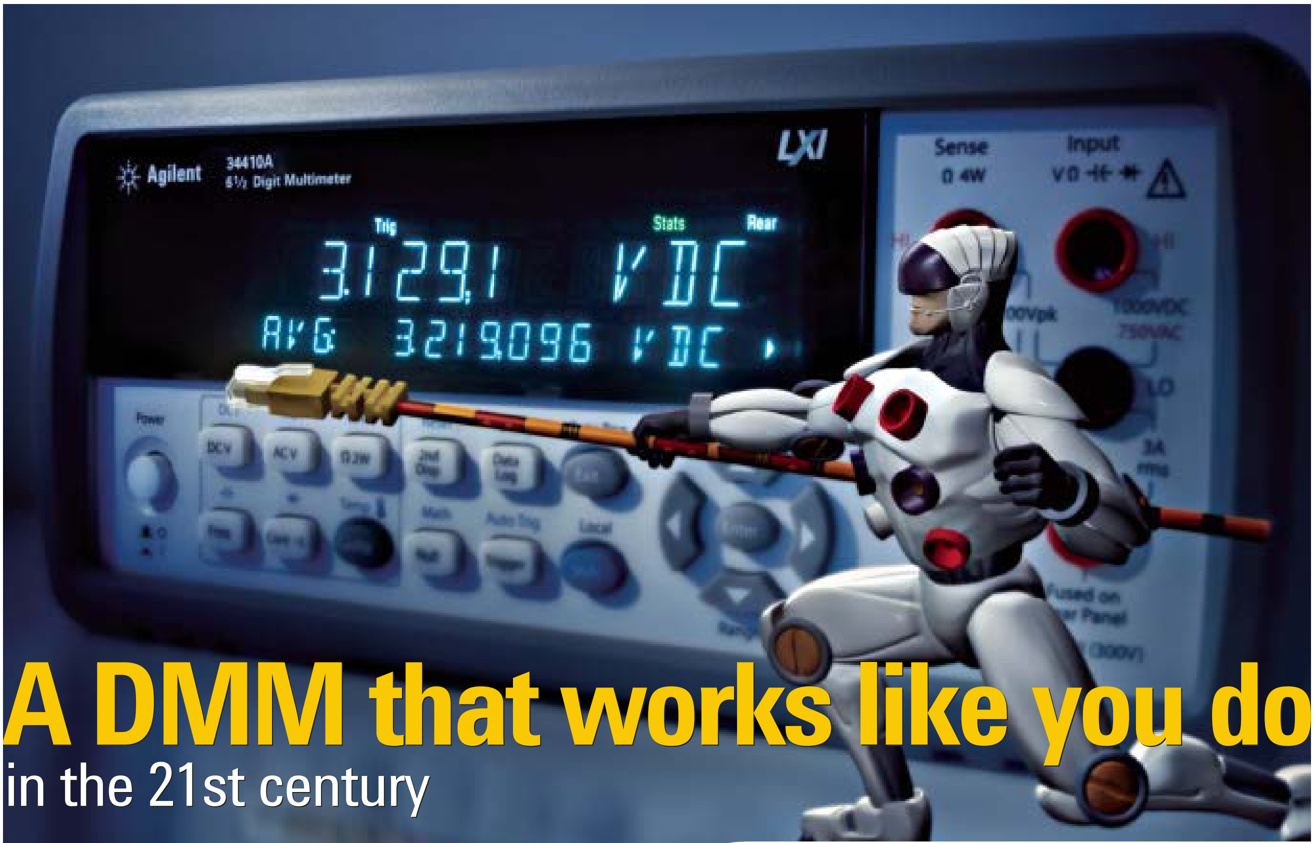


▲ *Fig. 4 Simplified analyzer block diagrams; (a) swept tuned spectrum analyzer (SA), (b) vector signal analyzer (VSA) and (c) real-time spectrum analyzer (RTSA).*

level triggering useless when taken directly after the down-conversion mixer. The RTSA's FMT can easily be set to ignore the CW leakage and trigger on the much weaker pulse event (see ***Figure 5***). Similarly, capturing weak echo returns in challenging EW environments is easily accomplished. The RTSA is also a multi-domain instrument capable of displaying time, frequency and modulation domain measurements. This allows the RTSA to replace several traditional instruments with a single portable unit. Since each measurement domain is derived from the same time synchronized record, measurements are precisely time-correlated. The operator can place a marker on a spectral or modulation anomaly and correlate it with the exact pulse that produced it. Time-correlated displays greatly enhance the diagnostic insight and reliability by providing a critical causality component. Traditionally, such precise time-correlated displays between separate instruments were difficult to obtain, re-



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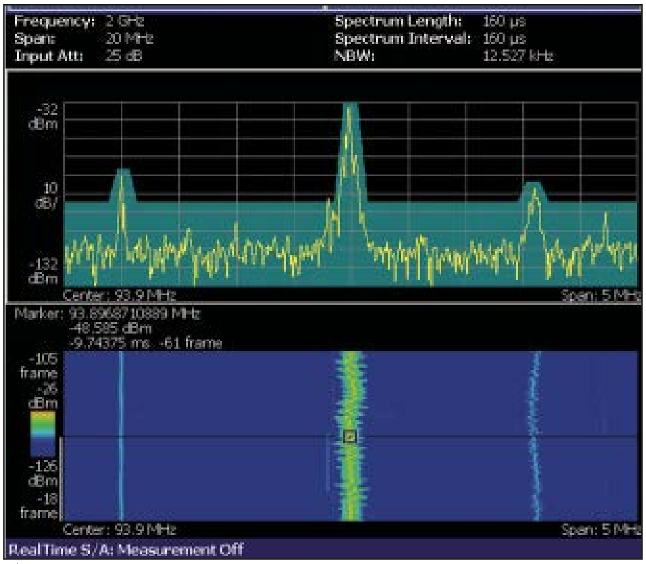
CAPTURING RADAR SIGNALS

Before signal analysis and diagnostics can begin, it is necessary to capture a recording of the signal of interest. The combination of comprehensive pulse measurement software, FMT and DSP hardware enable advanced RTSAs to convert time domain waveform samples into the frequency domain in real-time. The FMT can reliably capture elusive radar pulses or frequency abnormalities embedded in complex EW or real-world spectral backgrounds. The procedure for capturing pulse events of interest begins with setting up a frequency mask trigger. Complex frequency masks can be stretched around signals of no interest with a few mouse clicks, and the mask can be set just above the noise floor to avoid false triggers. Once the frequency mask is set up, any spectral event of interest that falls outside the mask will trigger a capture. In radar work, transient pulse returns are often well below the signal level of other nearby spectral emissions. This makes IF level triggering unreliable. The FMT, however, can compare the input signal's spectrum in real-time to the trigger mask, detecting even weak signal anomalies. Reliably finding the pulse is important, but once found there are other issues that can affect the display clarity and the accuracy of the captured data. Some modern RTSAs digitize the entire IF with a fast sampling analog-to-digital converter (ADC). These analyzers can seamlessly capture signals that require 36 MHz of spectral bandwidth and, with filters optimized for time domain measurements, can provide exceptional resolution — up to 20 ns on select RTSAs. This enables analysis of very narrow pulses and provides good detail of pulse shape (see ***Figure 6***). The time samples of the input signal taken by the analyzer are at a rate of at least twice the frequency of interest (Nyquist rate) or greater to avoid signal alias effects. The time samples are grouped into frames of data. Each frame contains the exact integer set of data necessary for the FFT process.

The fact that the data samples at each end of the frame do not continue beyond the frame, as they did with the original time samples before the frame was created, will artificially create an abrupt discontinuity. This discontinuity will cause spectral spreading when transformed from the time domain to the frequency domain. The frame itself is effectively now a "pulse." To minimize the effect of this discontinuity, a windowing function is used to scale the amplitude of the time-sampled data, reducing the amplitude of the samples on each end of the frame to zero. RTSAs generally offer a variety of popular windowing functions such as the Hanning, Hamming, Blackman, Blackman/Harris, Parzen, Welch and others. After the frame's data has been scaled by the windowing function, the FFT is calculated, transforming the data from amplitude ver-



▲ *Fig. 5 Frequency mask trigger — excluding a CW signal from a trigger event.*

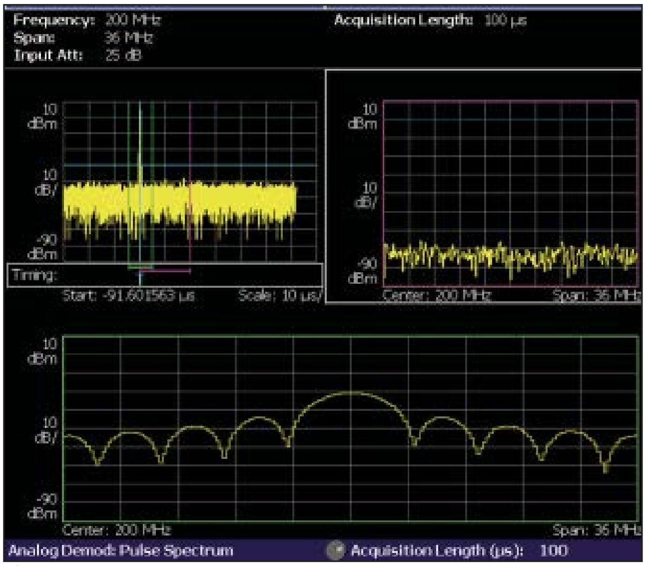
sus time to amplitude versus frequency. The FFT requires a variety of data computations to determine the amplitude of each frequency segment or "bucket." The FFT process assumes a continuous signal across the frame of data. Discontinuities or pulses that are shorter than one frame length can create errors in the amplitude of the spectral display. Signals with durations shorter than the full-frame length will be displayed with an amplitude that is proportionately lower than signals that occupy the entire frame. This presents a problem when analyzing radar pulses. Even worse, short pulses at the very end of the FFT frame suffer from additional reductions in amplitude or complete elimination by the windowing function. These effects can lead to significant measurement errors.[1] With pulsed signals, the most accurate FFT results are obtained when the pulse is centered in the data frame and the length is roughly the same as the frame. In effect, this makes the pulsed data more like continuous data.

ANALYZING RADAR SIGNALS

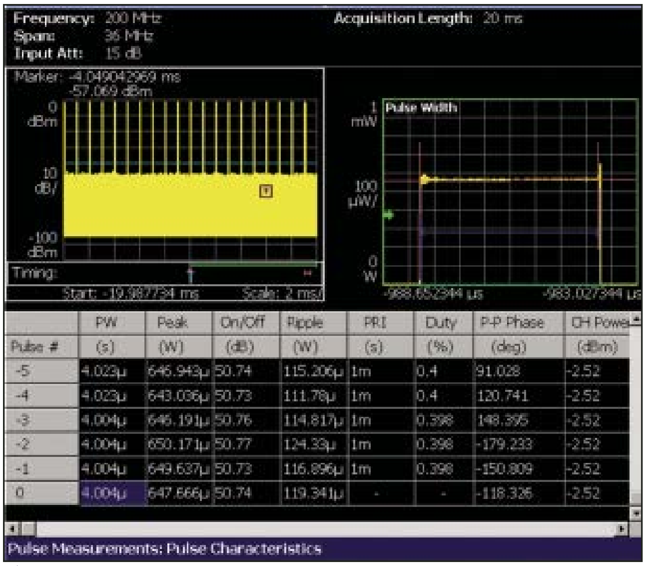
The modern RTSA's comprehensive pulse measurement software and time-correlated multi-domain displays provide extensive and largely automated radar signal analysis. The measurement software offers a wide variety of automated diagnostics designed for the characterization of radar signals, bringing the same speed and convenience to radar signal analysis that many high volume consumer RF devices have enjoyed for years. It also is less costly than specialized military ELINT pulse analyzers.

In conjunction with the time-correlated multi-domain displays, individual pulse characteristics can be quickly determined. Today's RTSAs can measure and graphically display pulse width, peak power, on/off ratio, pulse ripple, PRI, duty cycle, pulse-to-pulse phase, channel power, occupied bandwidth (OBW), effective bandwidth (EBW) and frequency deviation.

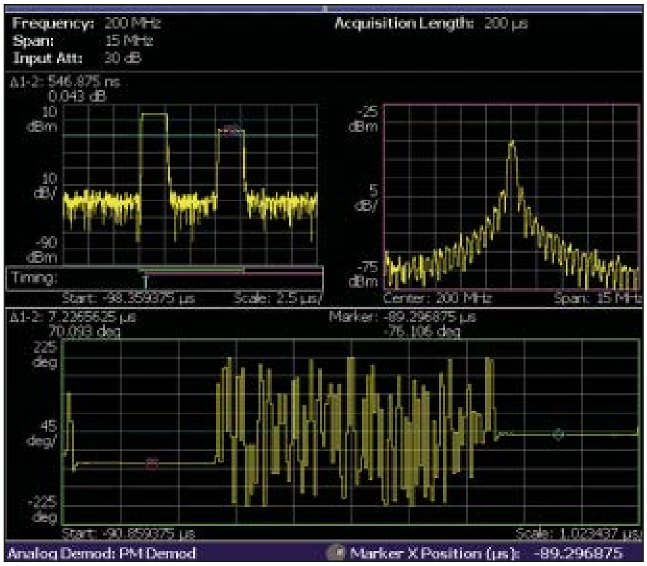
Since more than one pulse may be captured in a single recording, the RTSA has the capability to measure each pulse, assign a number to it and display a table of



▲ *Fig. 6 Real-time spectrum analyzer with 20 ns timing resolution.*



▲ *Fig. 7 Multi domain measurement with Pulse Measurement suite.*



▲ *Fig. 8 Measuring phase coherence between pulse doublets.*

measurement results automatically (see ***Figure 7***). With time-correlated displays, a pulse can be selected in the measurement table and a corresponding marker in the power versus time display will automatically correlate to it. The pulse will automatically be centered in the FFT window, meaning there will be no distortion of the pulse introduced by the FFT process. The unique software of the RTSA not only provides tabular data for each pulse measurement, but can also provide a graphical view. The graphical displays lend diagnostic insight by revealing trends. For example, as a radar transmitter heats up, its power operation may drift. Using a RTSA, the peak power for each pulse can be displayed graphically, making the power drift trend across multiple pulses easy to spot. Such measurements are not only helpful to the radar system designer and builder, but they can provide valuable information to the ELINT or EW specialist. Detailed signal trend analysis can provide confirmation as to the type of emitter being encountered.

MEASURING MULTIPLE PULSES

The RTSA can also be applied to multiple pulse measurements. One such example is the pulse doublet that is commonly used to test radar receiver performance. Two closely spaced pulses (pulse doublet) simulate echo returns from closely spaced target objects. Pulse doublets are great for testing a radar receiver's resolution ability. Using a signal generator, a variety of pulse doublet patterns and complex EW environments can be created for testing radar receivers. The RTSA is well equipped for validating these pulse doublet patterns and observing degradation caused by the receiver.

An example of diagnostic application using the pulse doublet is measurement of phase change between pulses traveling through a receiver subsystem. Some radar receivers use phase changes to measure the velocity of the target. Moving targets create

a Doppler shift in frequency between the transmitted pulse and the received pulse. The Doppler shift can be viewed as an accumulating phase shift between the transmitted signal and the received signal. Periodic measurement of the phase shift between the transmitted and received frequencies is a quick way to determine the relative velocity difference.

Maintaining receiver phase stability with differing echo return amplitude levels is therefore important for precise velocity measurements. Unfortunately, many components in the radar receiver chain can exhibit nonlinear effects, such as amplitude modulation to phase modulation (AM/PM) conversion, which can create unwanted phase shifts based on the amplitude of the echo return. These unwanted phase shifts will be interpreted as velocity errors.

Using the RTSA to determine receiver phase stability is a simple matter. First, the radar receiver is stimulated with a coherent pulse doublet of differing amplitude from a signal generator (see ***Figure 8***). Then the phase difference between the two pulses is observed at the output of the receiver chain. By selecting a phase demodulation display, the RTSA can graphically display the phase of each pulse versus time. The phase difference for static targets should be zero for a wide range of doublet amplitude differences. If phase stability is poor, higher dynamic range components may be required.

ANALYZING PULSE COMPRESSION

Compressed radar pulses also present measurement challenges. Radar pulse compression is used by many types of radar to improve both range and resolution. There is typically a tradeoff between improving resolution with narrower pulses and increasing range with wider pulses, yet pulse compression techniques can provide an increase in both range and resolution at the same time. By modulating the pulse, return signals that overlap can be separated. Therefore, a wider pulse can be used with greater energy without sacrificing range resolution.

There are many different pulse compression schemes and modulations. Typically, pulse compression is accomplished with either frequency or phase modulation to maintain a more constant pulse amplitude. The most common pulse compression modulation is the FM chirp, where a linear FM frequency ramp is used. In the receiver the FM chirp echoes are passed through a special filter which delays the low frequencies differently than the high frequencies. This has the effect of compressing the pulse or making it narrower in time. Pulses that were wide and overlapping emerge from the filter as distinctly separate pulses. Characterizing the compressed radar pulse adds the challenge of demodulating the pulse. The RTSA's multi-domain displays can analyze a compressed pulse's

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modulation in addition to making the normal pulse measurements. For example, an FM chirped pulse can be viewed in the power versus time domain, FM modulation domain and pulse measurement mode simultaneously. This allows easy inspection of the FM sweep linearity, pulse width, duty cycle and frequency deviation. Diagnostic assessments are further simplified with time-correlated displays. Placing a marker on one pulse will provide corresponding markers in the power versus time and modulation domain displays.

Similarly, the RTSA can analyze stepped frequency changes within a pulse. By viewing FM demodulation, the frequency-hopped steps in a pulse are readily apparent. Even a small amount of ringing can be seen as the phase lock loop transitions to the next frequency. This level of detail makes diagnostics of the pulse generation circuits a straightforward process.

Select RTSAs are also capable of analyzing compressed radar pulses that are phase modulated. The analyzer is simply placed in an analog demodulation mode with phase demodulation selected. In complex spectral environments, a frequency mask trigger is set to capture a recording of the pulse. Once recorded, the RTSA's demodulator will display the phase versus time, where the individual level transitions can be viewed. This can be important for many modern radar systems that use bi-phase modulation with orthogonal digital encoding to separate overlapping pulses and eliminate range ambiguity problems. In some cases, it is possible to use a selected RTSA's capability to perform digital modulation analysis on an individual pulse to obtain modulation quality information contained within a given pulse.

STREAMLINED TESTING AND ANALYSIS OF COMPLEX RADAR SIGNALS

Complex radar signal characterizations traditionally require multiple instruments and elaborate test setups. The transient nature of the radar pulse along with modern pulse compression schemes can make signal acquisition and accurate analysis a challenge. The modern RTSA is optimized for these transient RF signals. With unique capabilities such as frequency mask trigger, overlapping FFTs, automatic pulse centering in the frame and spectrogram zoom, the RTSA can reliably capture and display radar pulses even in complex EW spectral environments.

Pulse measurement software available for these instruments provides extensive automatic pulse characterization capability for the radar, EW and ELINT specialist. Automatic measurements streamline setup time and multi-domain displays enhance diagnostic insight, making radar system troubleshooting fast with reliable diagnostic conclusions.

Covering the gamut from simple pulse width measurements to complex demodulation of frequency hopping pulses, today's RTSA offers a new level of test and measurement capability that effectively replaces several traditional analyzers. Rapid automatic pulse measurements provided by the RTSA enhance the efficiency of product development, production and field maintenance operations. ■

Reference

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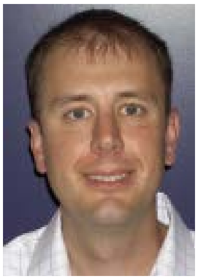


Matthew J. Maxwell *received his BSEE degree from the University of Washington, Seattle, WA, in 1995. He served as a US Navy officer aboard nuclear submarines, where he held various positions from communications officer to reactor control officer. Since joining Tektronix as product manager for real-time spectrum analyzers, he has worked with the communications and microwave industries on applications of spectrum analyzers.*

A MULTI-OCTAVE, OPEN-BOUNDARY, QUAD-RIDGE HORN ANTENNA FOR USE IN THE S- TO KU-BANDS

This article introduces a new antenna design to be used in anechoic chambers as a source antenna for 3D pattern measurements. When measuring 3D patterns, the receiving antenna in the anechoic chamber must be able to sense the two orthogonal components of the field that exist in the far field. This can be accomplished by mechanically rotating the source horn in the chamber. A better and faster approach is to use a dual-polarized antenna and electronically switch between polarizations. This new design is a broadband, ridged-guide horn (2 to 18 GHz) antenna with dual polarization.

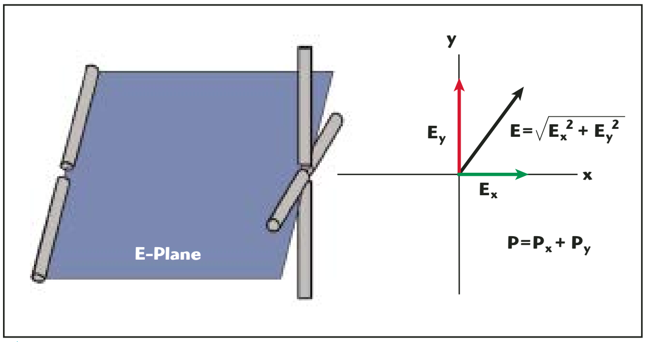
In a previous publication,[1] the author introduced a new dual-ridge horn that corrected the pattern problems of the traditional dual-ridge horn antenna.[2] All the parameters of this new horn, shown in ***Figure 1***, were measured and it was tested for use as an EMC immunity and emissions testing horn. It has also been tested for compact range illumination, showing a good performance in the low end of the frequency range and a small reduction in the diameter of the quiet zone (QZ) at the upper end. This horn was designed using MW Studio, a commercial package based on the finite integration time domain technique.

Fig. 1 A new double-ridged-guide horn.

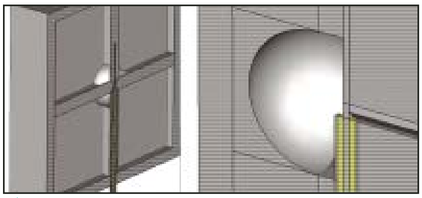
In this article, the concept of the new double-ridged-guide horn (DRGH) was taken to a higher level of versatility by creating a dual-polarized antenna. A dual-polarized antenna can measure both orthogonal field components simultaneously, which allows the engineer or technician to measure 3D patterns by rotating the antenna under test (AUT) in both azimuth and elevation. In addition, there is no need for an expensive rotational positioner to support the dual-polarized source antenna. The horn can be used in EMC compliance measurements. Since no mechanical rotation is necessary, the uncertainty in the measurement is reduced since the test set-up is left untouched for the different polarizations. If a dual-input receiver or an RF switch system is used, the test time can also be reduced. The importance of measuring 3D patterns is that

VICENTE RODRÍGUEZ
ETS-Lindgren
Cedar Park, TX

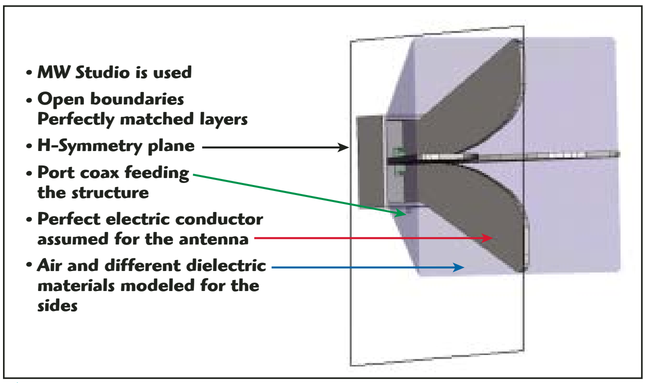
the total radiated power (TRP) can be calculated by integration over the measured pattern. The TRP is one of the parameters of interest when performing an over-the-air test, per the CTIA standard. As the antenna under test is rotated, the orientation of the radiated field vector is not known. By measuring both principal polarizations simultaneously, the total E field vector can be obtained independently of the direction of the radiating object and the polarization of its field (see ***Figure 2***). Consequently, a dual-polarized antenna is an integral part of a system used to measure the 3D patterns of antennas. In addition, there is a desire to use a broadband antenna to limit the number of measuring antenna changes in the system. The proposed horn provides these two characteristics. It is broad-banded, covering four octaves, and dual polarized.



▲ *Fig. 2 Measuring a random polarized field.*



▲ *Fig. 3 Ridges with an angle cut to fit the four ridges at the feed point.*



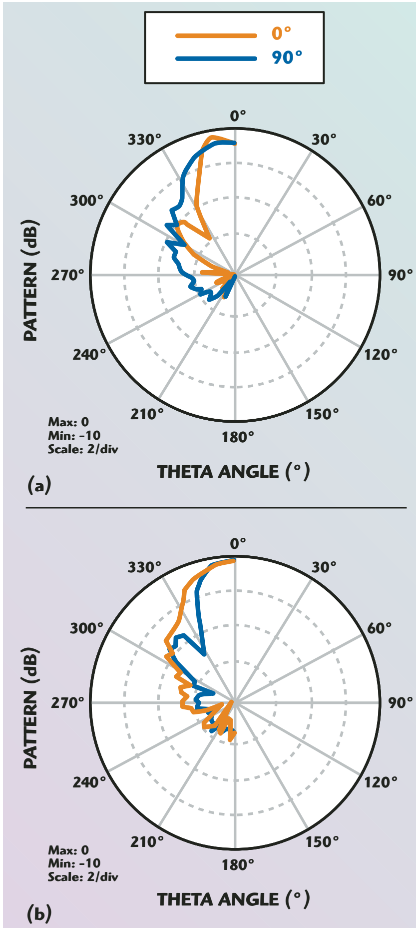
▲ *Fig. 4 The final design, showing the plastic, non-metallic sides.*

THE NUMERICAL MODEL

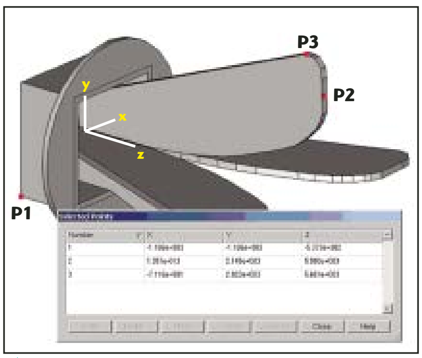
The design of the proposed horn started from the original DRGH design.[1] It preserves the shape of the ridges used before, only slightly modified to be able to add a set of two more ridges in the orthogonal plane, as shown in ***Figure 3***. The coaxial line feeding the antenna is also included in the numerical model. This provides a more accurate model than using a gap source between two opposite ridges. This approach, however, does require more unknowns for the model and therefore more memory. To use symmetry and reduce the memory requirements of the model, only one port is simulated. The other port is not introduced in the model. In the original design, it was found that the side structures of the traditional double-ridged horn affected the pattern by splitting the main beam. The model was set to have non-metallic sides with a relative permittivity of 2.5, the manufacturers' claim for polycarbonate plastics. ***Figure 4*** shows the new model with the plastic sides. The metallic part of the horn was simulated as a perfect electrical conductor (PEC) and the model was surrounded by a perfectly matched layer (PML). A plane of magnetic symmetry was used to reduce the computational domain in half. The final plastic-sided or open-boundary horn showed a good gain behavior and a fairly stable pattern for the upper half of the frequency range, the main beam remaining a single lobe for the entire range. The final design had overall dimensions of 6" by 6" aperture and approximately 6" in length.

COMPARISON BETWEEN NUMERICAL AND MEASURED RESULTS

Once acceptable results for patterns and input parameters were obtained, three prototype antennas were manufactured. The prototype's input parameters were measured and good agreement was found between the measurements and the model predictions. However, when measuring the pattern, it was discovered that, at the upper edge of the frequency range, the polycarbonate sides had an effect on the pattern behavior. The presence of the polycarbonate sides was causing the pattern to split at different frequencies. This was not fully



▲ *Fig. 5 Measured pattern at 18 GHz (a) with and (b) without polycarbonate sides.*



▲ *Fig. 6 Final design of the proposed horn.*

predicted by the model. One possibility is that, since only 10 cells per wavelength were used at the highest frequency in the time domain method approach, there is not enough accuracy in the predictions. A second possibility is that the dielectric permittivity was an approximation. The model used a constant value for the 2 to 18 GHz range. The actual material may have a frequency dependent permittivity that caused the unpredictable effects at the upper range. ***Figure 5*** shows the pattern with and without the plastic sides at 18 GHz. The numerical model was modified to take away the sides. Also, the sides on the prototypes were removed and the final horn design has no sides that can cause perturbation to the pattern. ***Figure 6*** shows the horn model without the sides. A flange was added to the horn feed cavity. The purpose of this flange is to attach the horn to the shield of the

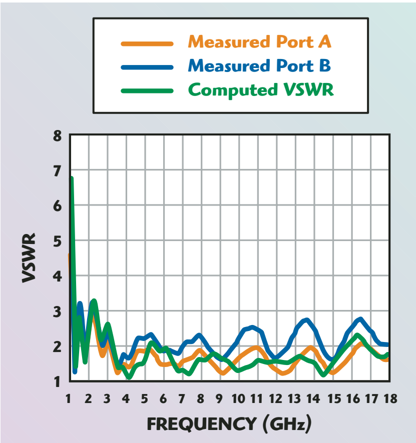


Fig. 7 Measured and computed VSWR of the proposed antenna.

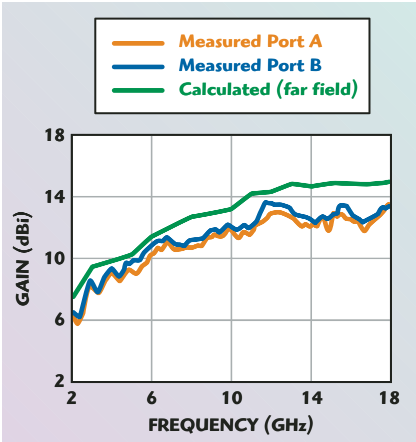


Fig. 8 Measured and computed gain of the proposed antenna.

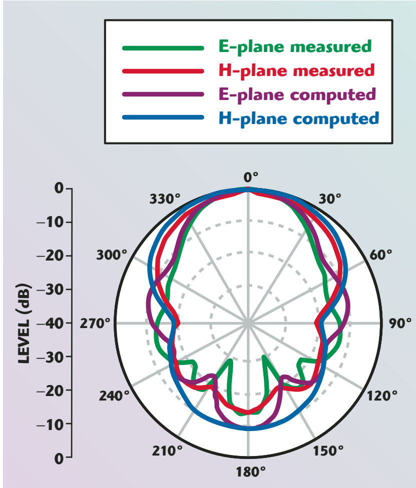


Fig. 9 Measured and computed patterns at 2 GHz.

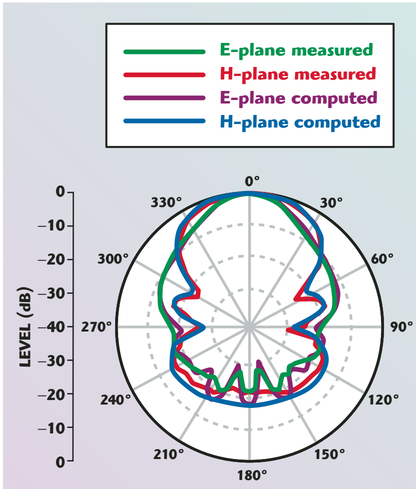


Fig. 10 Measured and computed patterns at 4 GHz.

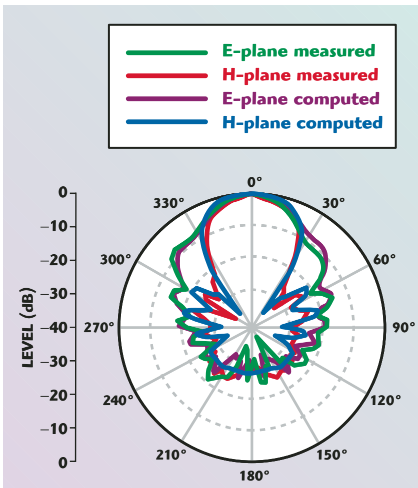
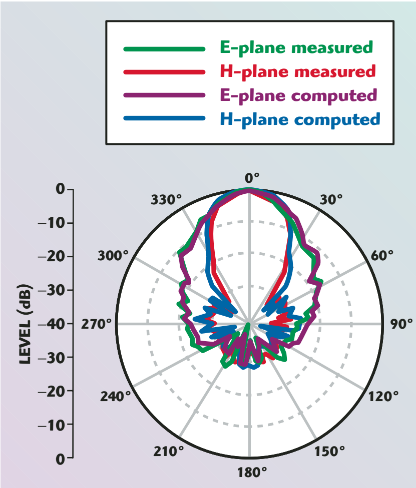


Fig. 11 Measured and computed patterns at 8 GHz.

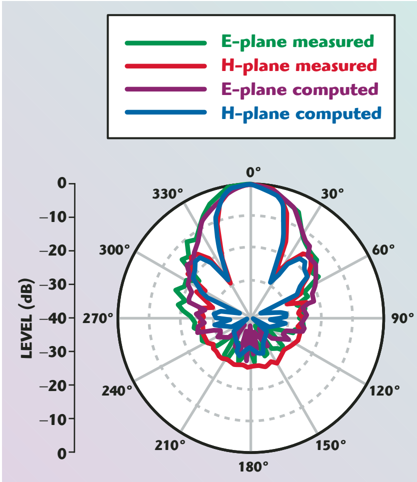
anechoic chamber keeping the cables outside the enclosure when measuring patterns. This same flange was added to the prototypes. ***Figure 7*** shows the VSWR for the computed port and for the ports of the prototype antenna without the sides.

The gain of the prototype horn was measured at 1 m, using the SAE ARP 958 revision C standard approach. Because that standard calls for the measurement to be done at 1 m from the face of the horn, it is the near field gain that is reported. This may explain the slight difference with respect to the computed results. There is still a very good agreement between the predictions and the measurements, as shown in ***Figure 8***.

The pattern was measured in a fully anechoic chamber at different frequencies. ***Figures 9*** to ***13*** show the comparison between the model predictions and the measured results for different frequencies. Very good agreement between the predicted and measured results can be seen in the figures. The difference is never larger than 2.5 dB between prediction and measurement in the front lobe. In the back lobes area, the differences can be larger. It may be caused by the positioning equipment

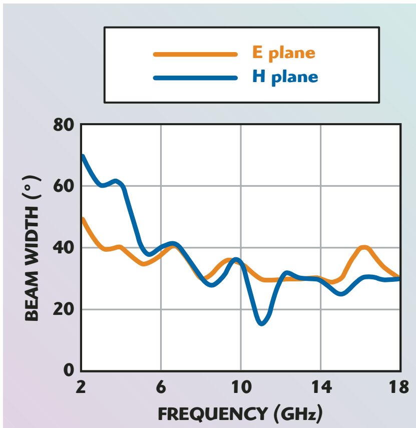


▲ *Fig. 12 Measured and computed patterns at 12 GHz.*

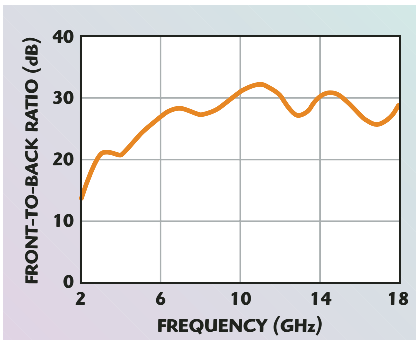


▲ *Fig. 13 Measured and computed patterns at 18 GHz.*

▲ *Fig. 14 The final configuration of the proposed antenna.*



▲ *Fig. 15 Half-power beam width for the proposed antenna.*



▲ *Fig. 16 Front-to-back ratio for the proposed antenna.*

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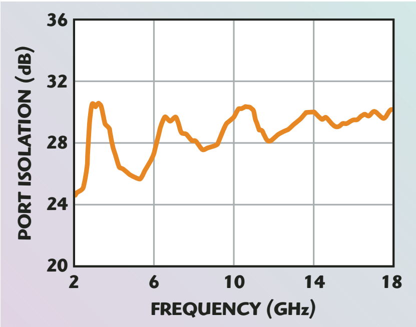

▲ *Fig. 17 Cross-port isolation for the proposed antenna.*

that supports the antenna. Although built of non-metallic materials, it may still block the radiation from the antenna during the measurement. In addition, as in the case of the 18 GHz measurements, the difference in the back lobes is caused by the measuring system running into the noise floor of the equipment. In all the cases shown, the model accurately predicted the position of the first null and the levels of the side lobes. ***Figure 14*** shows the final configuration of the horn. No sides enclose the ridges. Because of this lack of sides, the 'open-boundary ridged horn' name was coined to describe this type of antenna. Additional measurements were performed on the antenna. The 3 dB beamwidth and the front-to-back ratio were obtained from the pattern measurements. ***Figure 15*** shows the 3 dB or half-power beamwidth for the new design. ***Figure 16*** shows the front to back ratio. Since the numerical model only contained one port and coaxial feed, one of the parameters that could not be predicted during the modeling phase was the cross-port isolation. The cross-port isolation is a limiting factor on the cross-polarization isolation of the antenna. It is obtained from an S_{21} parameter measurement, where a signal is injected into one port and the output on the orthogonal port is measured. ***Figure 17*** shows that the cross-port isolation is higher than 25 dB over the whole frequency range.

CONCLUSION

This article has presented a new quad-ridge horn antenna design without sides. This "open-boundary" horn has shown a stable pattern for the upper half of the frequency range as can be seen from the flatness of the gain and the 3 dB beamwidth. The resulting antenna is intended for use in anechoic chambers to measure the patterns of other antennas. Since the antenna covers multiple octaves, it is possible to measure a large variety of antennas without changing the measuring antenna in the chamber. In addition, the antenna can be used as a broadband antenna in EMC emissions measurements. Future work must be done in testing the potential of the antenna as a source in tapered chambers to see its capabilities. The potential for its use in compact ranges should also be studied. ■

ACKNOWLEDGMENTS

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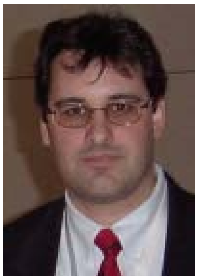

Vicente Rodríguez *received his BSEE, MS and PhD degrees from the University of Mississippi in 1994, 1996 and 1999, respectively. He joined the department of electrical engineering and computer science at Texas A&M University-Kingsville (formerly Texas A&I University) as a visiting assistant professor in 1999. In June 2000 he joined EMC Test Systems (now ETS-Lindgren), where he is currently the senior principal antenna design engineer in charge of the development of new antennas for different applications and on improving the existing antenna line. His interests include numerical methods in electromagnetics, especially when applied to antenna design and analysis. He is the author of more than twenty publications including journal and conference papers as well as book chapters. He holds patents for hybrid absorber design and for a new dual-ridge horn antenna design for EMC applications.*


MODERN • ART

ANECHOIC CHAMBER MEASUREMENT IMPROVEMENT

The well known and widely used "Termination-VSWR" method, used to measure the reflectivity of an absorber wall in an anechoic chamber, has been considerably modernized with the help of new vector network analyzers (VNA) and personal computers (PC), taking advantage of fast sweepers or synthesizers and of the time-domain capability, both automated by the PC. In the past, the measurement, using a slotted line, was made one frequency at a time. It is now possible to cover a complete range of frequencies, with no moving parts, using two different methods: the Advanced VSWR (AVSWR) or the radar cross-section (RCS) method. It is not an exaggeration to say that the progress made in this measurement is as high as the transition between a slotted line measurement and the automated VNA at the end of the 1970s. These new methods allow measuring a complete range of frequencies in the same time it took to measure only one or two frequencies before.

GENERAL CONSIDERATIONS

As a matter of fact, the VNA replaced the slotted line a long time ago to measure RF and microwave components because it was more accurate, it provided phase information and it was possible to measure S-parameters over a full bandwidth in a very short time. The availability of accurate phase measurements, mainly due to the use of synthesizers to produce the RF and microwave signals and to the accurate system calibration, has enabled sophisticated mathematical treatments to be made on the measured signals such as Fourier transform, allowing calculation of echoes in the time domain, filtering and removal of unwanted echoes (time-gating capability), and returning back to the frequency domain with an improved measurement accuracy. The same methodology can now be used also to measure the voltage standing wave ratio (VSWR) of an absorber wall over a full bandwidth, with improved accuracy and in a shorter time. For that purpose, the transmitter/receiver and the stub tuner are now replaced

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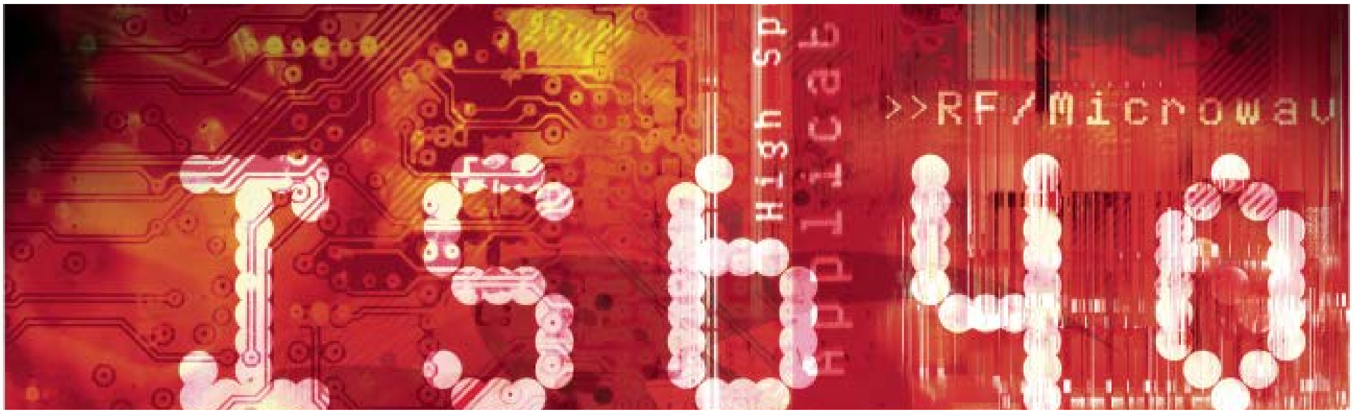

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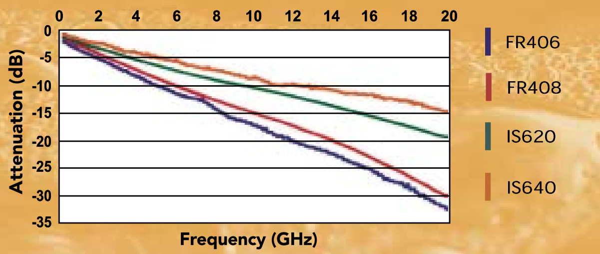

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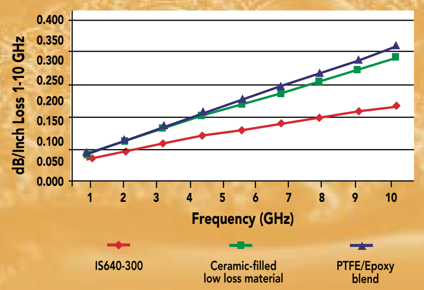

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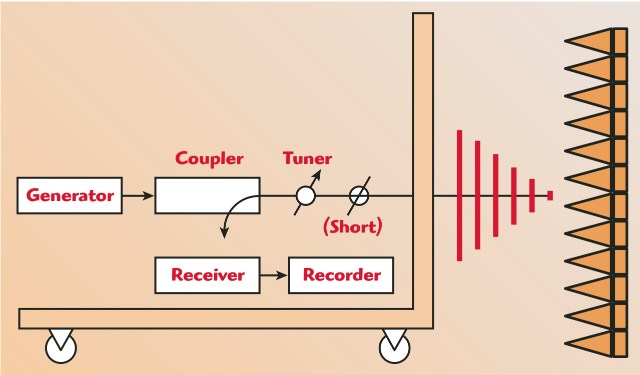


▲ *Fig. 1 Test set-up for measurements using the Termination-VSWR method.*

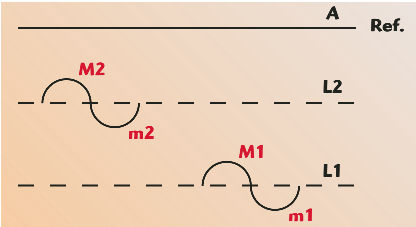
by a VNA with possibly a time-gating capability (time-domain option). This article will first describe the classical Termination-VSWR measurement method, then the new AVSWR and RCS methods.

PREVIOUS VSWR MEASUREMENT METHOD

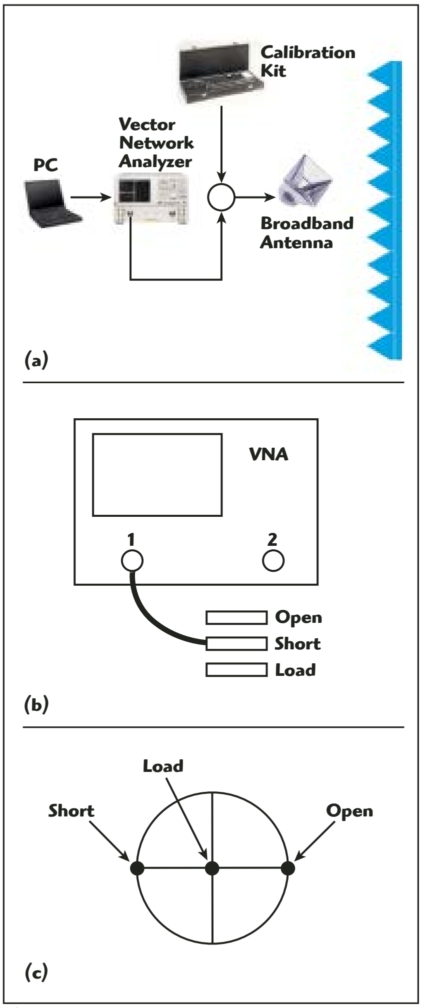
In the past, to measure the VSWR of a device connected to a line, a conventional slotted section was included in the transmission line feeding the device so that the minimum and maximum levels detected on this line gave the load VSWR, hence its reflection coefficient. The previous Termination-VSWR method was based on this principle to connect a transmitter/receiver to an antenna pointing to the absorber wall under test, and simulate the probe movement in the slotted line by moving linearly the cart carrying the antenna and transmitter/receiver. For better accuracy at low VSWRs, a stub tuner was included before the antenna to reduce the antenna VSWR and enhance the received variations when moving the cart in front of the wall. ***Figure 1*** shows the basic test set-up used.

The measurement procedure is summarized below:

1. The set-up equipment was located on the cart, with the antenna directed towards the wall to be measured.
2. The reference level for 100 percent reflection (short circuit) was obtained by replacing the antenna with a short circuit (with no tuner on the line). This level was recorded as level A or Ref. (see ***Figure 2***).
3. The short circuit was removed and the antenna reconnected with a stub tuner in between.
4. The stub tuner (generally a coaxial triple stub tuner for easier tuning) was tuned to obtain as low a signal level as possible. When the signal level got too low (that is in the noise floor), then the power level was increased. This increase in decibels was noted on the recorder paper (level L1).



▲ *Fig. 2 Termination-VSWR data recording example.*



▲ *Fig. 3 Typical AVSWR test set-up (a), calibration (b) and verification (c).*

5. The cart was moved either forward or backward along its line-of-sight over a distance relatively small, compared to the distance between the antenna and the absorber wall (generally a few wavelengths, but by a minimum of $\lambda/2$ to be sure to have at least a maximum and a minimum). A standing wave pattern was recorded with a minimum level m1 and maximum level M1. Level m1 was caused by the equipment reflected field level (Y) minus the absorber reflected field level (B)

$$m1 = 20\log\frac{Y-B}{A} \qquad (1)$$

Level M1 was caused by the equipment reflected field level plus the absorber reflected field level (B)

$$M1 = 20\log\frac{Y+B}{A} \qquad (2)$$

With m1 and M1, one could calculate two reflected field level values

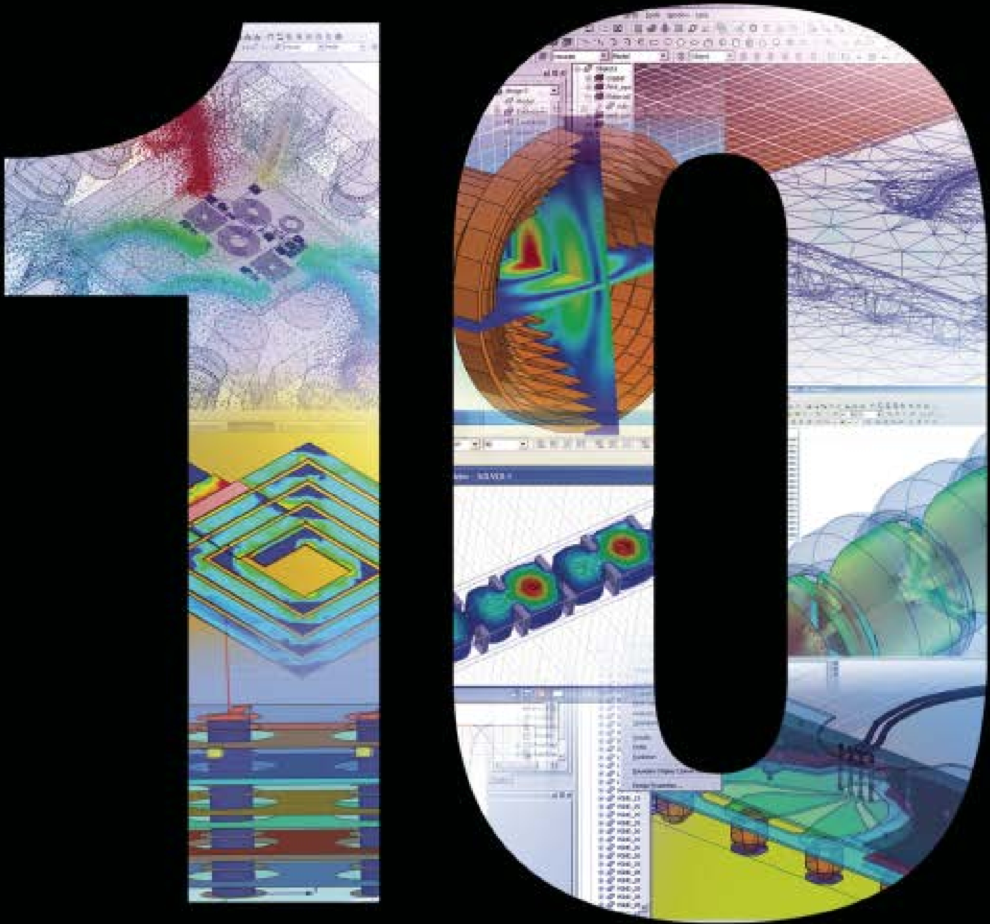
$$V1 = \frac{Y}{A} \text{ or } \frac{B}{A} = \frac{1}{2}\left(10^{\frac{-M1}{20}} + 10^{\frac{-m1}{20}}\right)$$

$$V2 = \frac{B}{A} \text{ or } \frac{Y}{A} = \frac{1}{2}\left(10^{\frac{-M1}{20}} - 10^{\frac{-m1}{20}}\right) \qquad (3)$$

6. In some cases, it was not clear which one was the actual reflected field level value of the absorber or of the equipment. Therefore, a second measurement had to be performed.
7. The stub tuner was set to another level such as level L2.
8. The translation (Step 4) was repeated and another standing wave pattern was recorded. The results were the new minimum level m2 and maximum level M2.
9. In the same way as for the first standing wave pattern, two reflected field level values were obtained

$$V3 = \frac{Y}{A} \text{ or } \frac{B}{A} = \frac{1}{2}\left(10^{\frac{-M2}{20}} + 10^{\frac{-m2}{20}}\right)$$

$$V4 = \frac{B}{A} \text{ or } \frac{Y}{A} = \frac{1}{2}\left(10^{\frac{-M2}{20}} - 10^{\frac{-m2}{20}}\right) \qquad (4)$$



10. Between the first and second measurement the reflected field level of the absorbers (B) did not change. However, by changing the setting of the stub tuner, the reflected field level of the equipment (Y) changed. Therefore, the two identical values out of the four, V1 = V3 or V4, or V2 = V3 or V4 corresponded to the reflectivity (linear) of the absorbers. Examples of the recording and calculations are given in ***Appendix A***.

This method was powerful but rather slow because only one frequency could be measured at a time (receiver limitation), and many cart positions were necessary to find contiguous maximum and minimum levels (slotted line method limitation). Also, with the cart and receiver accuracies, this method was almost never used above 12 GHz.

Now that recent VNAs with time-domain capability and broadband directive antennas exist, it has become possible to modernize the "VSWR method" with two methods:

The "Advanced VSWR method" to measure an absorber wall VSWR. This method works fine between 0.5 and 6 GHz with the help of a wideband horn antenna.

The "RCS method," for 6 to 18 GHz, which measures the wall reflectivity through its radar cross-section with a quasi-monostatic bench using two wideband horn antennas, located close to each other.

THE AVSWR MEASUREMENT METHOD

Figure 3 shows the equipment necessary to perform this type of measurement. It includes a VNA (covering the requested frequency range), with the time-domain option, a calibration kit for S_{11} (reflection) measurements, that is a short, an open and a broadband 50 Ω load, a broadband directive antenna, an antenna pylon or tripod to hold firmly the antenna during the measurements, good quality 50 Ω coaxial cables to connect the antenna to the VNA, microwave absorbers to cover the floor between the antenna front and the wall to reduce unwanted echoes, a yardstick to measure the antenna height and the antenna to wall distance, and optionally (but useful) a computer to record the data and drive the VNA through the right interface (generally GPIB).

The AVSWR procedure can be summarized as follows:

1. The antenna is pointed towards the wall at a close distance (approximately 1 m from the absorber tips).
2. The VNA is calibrated at the end of the cable, for S_{11} with the calibration kit short, open and load. If a sliding load is supplied in the calibration kit, the calibration will, of course, be better with it.
3. The calibration is verified by reconnecting the standards (open, short, broadband load) and check in log-amplitude and Smith charts or polar chart that the points are located correctly. Then, record the calibration in memory. Note: one should see on the polar plots of the short, open and load at the places represented (case of a perfect S_{11} calibration).
4. The broadband antenna is connected to the VNA and the time-domain mode of the VNA is selected,

generally in the band pass time-gating mode (refer to the VNA manual for more details). The screen now shows the time-domain response in reflection, including antenna and wall reflection.

5. One validates the time gating and selects the frequency domain. The curve (S_{11} log mag. mode) now shows directly the reflection coefficient of absorber wall in decibels as a function of frequency.

This AVSWR method is much simpler than the Termination-VSWR one. The complete reflectivity curve is obtained without any antenna movement. This is a real improvement in measurement speed and quality. If the time-domain option is not included in the VNA, the time gating can also be made by the associated PC, with the direct fast-Fourier transform, filtering and then reverse fast-Fourier transform.

THE RCS MEASUREMENT METHOD

To verify the RCS specifications of an anechoic chamber, or the reflectivity of a specified wall, it is possible to perform RCS measurements of a standard RCS target (called reference target) and to compare it with the RCS of the empty room. A typical set-up used for the RCS measurement is shown in ***Figure 4***. The method justifications are shown in Refs. 1 and 2, although it is useful to note that

$$RCS = \sigma = \pi R^2 Re$$

is the linear equation relating the RCS of a receive wall covered with absorbers at a distance R to the antennas and Re the linear absorber reflectivity. This equation is also approximately true for the receive wall of a fully anechoic chamber as the other walls have negligible effects.

Expressed in decibels, this equation becomes

$$RCS_{chamber}\ (dBm^2) = Re\ (dB) + 10 \log (\pi R^2)\ (dBm^2 \text{ or } dBsqm, \text{ if R in m})$$

This method is convenient and more "natural" for RCS chamber but also to replace or modernize the classical Termination-VSWR method, which in addition gives the reflectivity of an absorber wall under normal incidence.

To perform the measurements, the following equipment is required:

- A VNA (covering the requested frequency range), with good sensitivity and time-domain option.
- Two broadband directive antennas covering the frequency range, or one broadband directive antenna associated with a directional coupler for a real monostatic measurement. The bandwidth of each antenna must be sufficient to have a time-domain resolution able to isolate the antenna(s) from the wall.
- Antenna pylons or tripods to hold firmly the antennas during the measurements.
- At least one metallic reference RCS target to make the reference measurement with its transparent pylon (expanded polystyrene, for example).
- A manual or automated positioner to locate the RCS reference target at the right elevation and azimuth an-

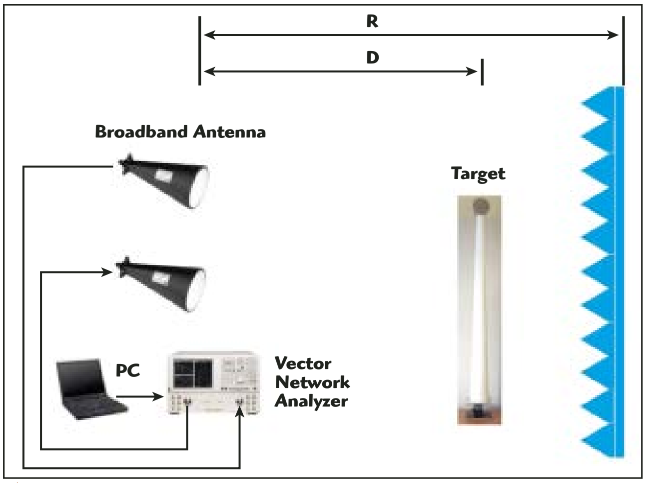
gles in front of the antennas (if a directive flat target), not necessary in the case of a sphere reference target (omni-directional target).

- Good quality 50 Ω coaxial cables to connect the antennas to the VNA.
- Eccosorb absorbers to cover the floor between the antenna front and the wall to reduce unwanted echoes (if necessary), and also to reduce direct coupling between antennas.
- Means to determine the distances between antennas and wall (R) and between antennas and target (D).
- Optionally (and usefully) a computer to record the data and drive the VNA through the right interface (generally GPIB).
- Optionally (if necessary) a low noise amplifier (LNA) with its DC supply to enhance the received signals so that the signal-to-noise ratio is sufficient to have correct accuracy.

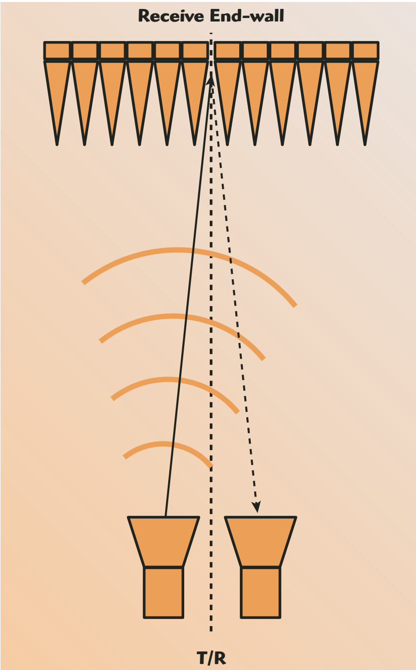
The RCS Procedure can be summarized as follows:

1. The antennas are installed on their pylons or tripods, pointed towards the receive wall at a distance R from the absorber wall (see ***Figure 5***).
2. The broadband antennas are connected through their respective 50 Ω cables to the VNA ports (port 1 for the transmit antenna and port 2 for the receive antenna, if the VNA has a classical test set, or an equivalent connection in the case of transmitter/receiver capability).
3. The time-domain mode of the VNA (generally band pass, time-gating mode) is selected. The screen now shows the time-domain response, including antennas coupling and wall reflection.
4. The time gating (around wall) is validated and frequency domain is selected. The curve (S_{21} log mag. mode) now directly shows the reflection level of the absorber wall in dB, also called empty room level "Emp."
5. One then sets the metallic RCS reference target in the middle of the quiet zone on its low RCS pylon above a positioner at a distance D from the antennas (see ***Figure 6***). The RCS reference target is a known RCS target (conducting flat plate or a metallic sphere or a metallic trihedron, etc.). If the target is a sphere or a well-oriented trihedron, no positioner is needed, since they are almost omni-directional targets.
6. One selects the time-domain mode of the VNA. The screen now shows the time-domain response, including antennas coupling, target and wall reflection. The gating must now start before the target and finish after. One then validates the time gating and selects the frequency domain mode. The curve (S_{21} log mag. mode) now directly shows the reflection level of the RCS reference target in dB, also called reference level "Ref" (if no other obstacle can exhibit reflection in the same time-gating window).
7. From the linear "Emp" and "Ref" measured data, one computes the RCS of the receive wall, which is also the anechoic chamber RCS. The absorbers reflectivity is obtained from the following formulas

$$RCS_{chamber} = RCS_{ref}(Emp/Ref)^2(D/R)^4 \ (m^2)$$



▲ *Fig. 4 Typical set-up for the RCS measurement of the reflectivity of a wall.*



▲ *Fig. 5 "Empty room" measurement set-up.*

RCS_{ref} being the theoretical reference target RCS, given in dBm^2 or dB_{sqm}.

$$RCS_{chamber}\,(dBm^2) = RCS_{ref}\,(dBm^2) + Emp\,(dB) - Ref\,(dB) - 40\log(R/D)$$

Note: 40 log(R/D) is the distance correction factor added to Ref RCS as this target is not at the same distance from the antennas as the wall. The wall absorber reflectivity can be then deduced from

$$RCS_{chamber} = \pi R^2 Reflectivity$$

or, in dBsqm

$$Reflectivity\,(dB) = RCS_{chamber}\,(dBm^2) - 10\log(\pi R^2)\,(dBm^2)$$

COMPARISON BETWEEN THE OLD (VSWR) AND NEW (AVSWR AND RCS) METHODS

The AVSWR was used to test anechoic chamber walls, with a configuration shown in ***Figure 7***, with a wideband horn on a tripod associated with a compact VNA and a laptop.

This technique was originally validated on a dedicated test wall covered with 16 pieces (4 × 4 square) of 2 × 2 feet VFX-18-NRL absorbers (18 inches high pyramidal absorbers).

The curves shown in ***Figure 8*** are the results obtained with two different horns in the same position, for the same wall. These two curves are quite similar in their common part and very close to the VFX-18-NRL performance measured on classical NRL Arch (green line).

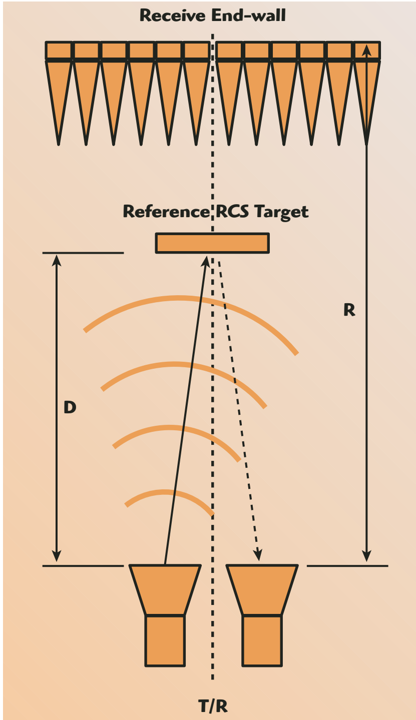
Figure 9 shows the RCS experiment conducted on a recent anechoic chamber to measure the absorber wall reflectivity. The old Termination-VSWR method was also used at selected frequencies to validate the RCS method. In ***Figure 10*** the blue line between 6 and 18 GHz is obtained with this RCS method and shows a good agreement with the VSWR method (red dots). Between 0.5 and 6 GHz, the AVSWR method was used and the comparison with the VSWR method also shows a good agreement (green line).

CONCLUSION

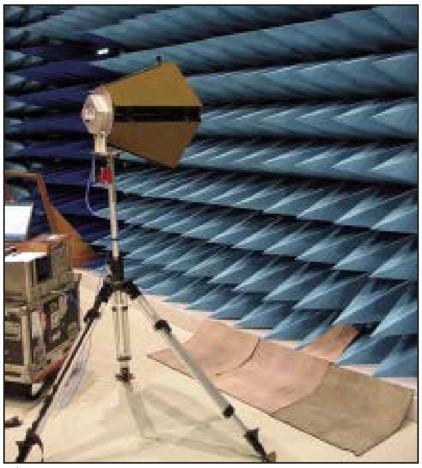
The classical Termination-VSWR method was powerful but rather slow because only one frequency could be measured at one time (receiver limitation), and many cart positions were necessary to find contiguous maximum and minimum levels (slotted line method limitation). Also, because of cart and receiver accuracy, this method was almost never used above 12 GHz.

It is now possible to use two new methods:

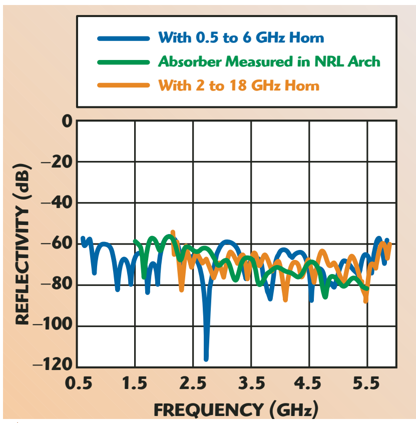
- The "Advanced VSWR method"



▲ *Fig. 6 Reference target measurement set-up.*



▲ *Fig. 7 Advanced VSWR set-up example for the 0.5 to 6 GHz range.*



▲ *Fig. 8 VFX-18 wall measurements with the Advanced VSWR method.*

to measure an absorber wall VSWR. This method works fine between 0.5 and 6 GHz with the help of a wideband horn antenna.

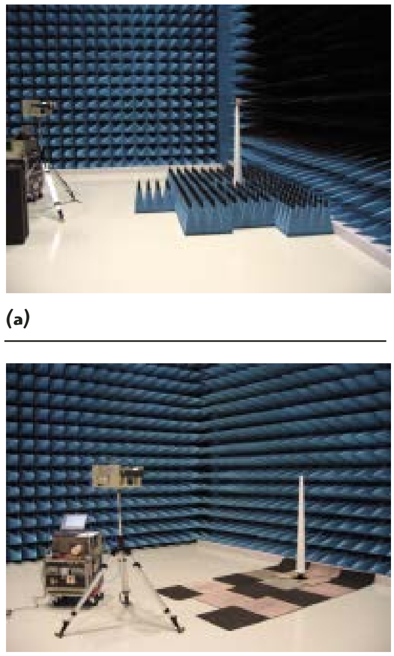
- The "RCS method," for 6 to 18 GHz, which measures the wall reflectivity through its radar cross-section with a quasi monostatic bench using two wideband horns antennas, close together. This RCS method is, of course, more natural for RCS chambers.

The first measurements that were done with these two methods show a good agreement with microwave absorber performance and with the results obtained from the previous VSWR method.

The "Advanced VSWR method" is the natural evolution of the Termination-VSWR method, taking into account the possibilities that are given by the up-to-date equipment, such as vector network analyzers, wideband horn antennas and personal computers.

At this time, this method has shown to be efficient and valid between 500 MHz and 6 GHz with a standard wideband horn antenna. The frequency range could be extended, depending largely on antenna bandwidth and directivity.

The "RCS method," which is not as new, but is not widely used in anechoic chamber testing, has been more often used in RCS chamber measurements. Even if more complex than the AVSWR method, it is still a reliable and not too complex method to measure not only the RCS but also the reflectivity of an absorbing wall. It is now used



(a)

(b)

Fig. 9 RCS set-ups with different floor coverings.

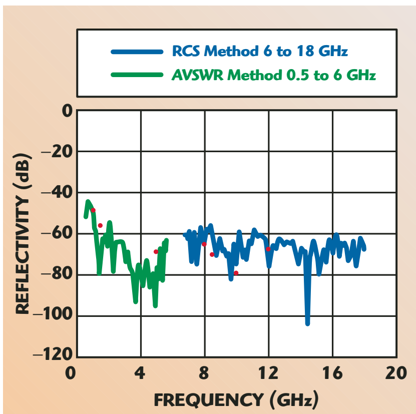


Fig. 10 AVSWR and RCS results compared with VSWR points.

between 6 and 18 GHz with standard double ridge wideband horns, although the frequency range could also be extended. ■

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Yoeri Arien *received his engineering degree in telecommunications from Hogeschool Limburg, Belgium, in 1996.*

APPENDIX A

TERMINATION–VSWR METHOD RESULT EXAMPLE

For a certain setting of the stub tuner, pattern 1 is obtained (see ***Figure A1***).
Maximum level M1 = –18.1 dB
Minimum level m1 = –22.6 dB

Converting these values into reflected field level values:

Maximum level M1 = 0.124451461
Minimum level m1 = 0.074131024

VSWR1 =

$$\frac{M1+m1}{2} = 0.099291243 = -20.1\,\text{dB}$$

VSWR2 =

$$\frac{M1-m1}{2} = 0.025160219 = -32.0\,\text{dB}$$

A second setting of the stub tuner gives pattern 2:

M2 = –14.8 dB = 0.181970086
m2 = –17.2 dB = 0.138038427

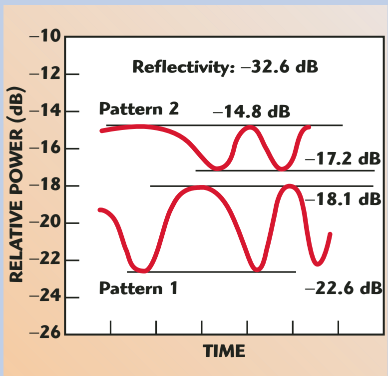
VSWR3 =

$$\frac{M2+m2}{2} = 0.160004256 = -15.9\,\text{dB}$$

VSWR4 =

$$\frac{M2-m2}{2} = 0.021965830 = -33.2\,\text{dB}$$

Comparing reflected field levels 1 and 2 with reflected field levels 3 and 4 shows that reflected field levels 2 and 4 must be from the absorber and reflected field levels 1 and 3 from the equipment. In theory the absorber values should be exactly the same but in practice they can differ a little. In these cases one takes the average between reflected field level 2 and reflected field level 4. The resulting performance is –32.6 dB.



▲ *Fig. A1 Data sheet for the Termination-VSWR method example.*

AN EFFICIENT, INTERACTIVE OPTIMIZATION SOLUTION FOR ANALOG AND RF DESIGN

Optimization has been applied to circuit design for decades. IBM pioneered circuit simulation-based optimizer research in the 1960s and '70s. In the 1980s, the University of California at Berkeley extended the research with more exotic algorithms and interactivity with programs such as DELIGHT and ECSTACY. During the same period, AT&T Bell Labs, using a program called TILOS, used optimization for transistor sizing of custom digital circuits in order to improve timing performance. Today, optimization products can be obtained from most major electronic design automation (EDA) providers.

Microwave designers have traditionally applied optimization widely to improve and center the performance of their circuits. However, even though optimization has long been an established workhorse for microwave designers, its application in analog integrated circuit (IC) design has been hampered by poor ease-of-use and performance. This tutorial describes a fast, easy to use and highly interactive optimization solution that is very effective for analog and RF/microwave applications.

This tutorial describes a fast, easy to use and highly interactive optimization solution that is very effective for analog and RF/microwave applications.

As opposed to some circuit optimizers on the market that require tedious setup and run mostly in a batch mode, the solution described in this article is designed for easy setup and interactive use during the circuit design creation process. While many solutions offer just one algorithm, this one offers a number of different optimization algorithms and methods that can be applied depending upon the problem definition and breadth of the design space to be explored. Many of these algorithms begin at a user-defined starting point and search the design space from that point to find the local optimum. Some, like Genetic and Pointer, can search the entire design space to find the global optimum. These particular algorithms can even handle discrete component and subcircuit choices that can be used to synthesize circuit structure. Some of the unique and powerful features of this optimization solution are demonstrated in the following example. A list and descriptions of all the algorithms included are shown in ***Appendix A***.

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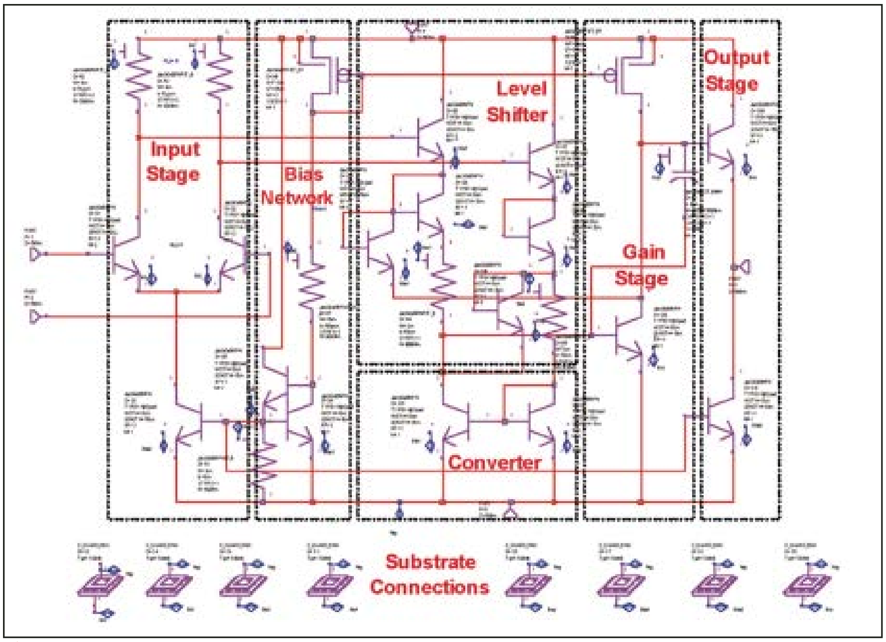

Fig. 1 Operational amplifier schematic.

DESIGN AND OPTIMIZATION OF A HIGH FREQUENCY OPERATIONAL AMPLIFIER

The schematic of the amplifier to be optimized is shown in ***Figure 1***. The application is to amplify intermediate broadband signals up to 2 GHz. As an operational amplifier, it will always be used in a closed-loop configuration, which is a real challenge at these frequencies. Consequently, it is imperative that the phase shift through the amplifier be kept to a minimum. Because of the high frequency requirements, the amplifier will use a leading foundry 60 GHz silicon germanium technology. In this technology, the NPN bipolar transistor is the active device of choice, since all other transistor types are significantly lower in performance. Therefore, the signal path is kept simple and mostly NPN-based except for one P-channel metal-gate transistor (PMOS) load device. The architecture of the circuit is typical of most operational amplifiers and is made up of the following building blocks:

- Input Stage – a classical differential transistor pair gain circuit driving matched resistive loads and biased by a current source.
- Voltage Level-shifter – differential emitter-followers that drive diode- and resistor-level-shifters into a differential-to-single-ended converter.
- Differential-to-single-ended Converter – as the name implies, this circuitry converts the differential voltage through the level-shifter to a single-ended signal.
- Common emitter Gain Stage with PMOS current source load. This stage is driven by the output of the converter and generates most of the gain of the amplifier.
- Emitter follower Output Stage with NPN current source bias – this stage buffers the gain stage high impedance node from the output load.
- Bias Network – this relatively simple circuitry establishes all the current sources in the amplifier. A more complex bias network could significantly reduce the variability of the amplifier over power supply changes, but that is an exercise for another time.

Figure 2 is a view of the optimized amplifier layout.

DESIGN PROJECT SETUP

Setting Up Test Benches and Corners of Interest

The operational amplifier project is configured into three test benches — one each to measure DC, AC and transient performance specifications. The amplifier is also rated to operate over positive power supply voltage corners of 3.7 to 4.3 V and a load ca-


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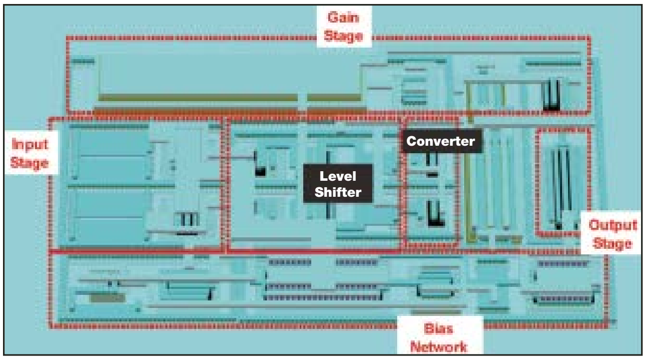


Fig. 2 The optimized amplifier output.

pacitor range of 0 to 1 pF. Accordingly, parameter sweep blocks are included in all the test benches for the power supply and load capacitor. Any number of parameter sweeps can be defined, including temperature and process corners.

Defining Measurements and Optimization Objectives/Weights

For this amplifier, the goal is to meet or exceed the bandwidth and gain requirements, while at the same time minimizing power and maintaining stability. As might be expected, these are very conflicting requirements. Designers can spend many tedious hours and even days trying to meet specifications, much less finding the best solution. Often, in the interest of time, designers will settle for an acceptable solution without pushing the design for all it can deliver. This is where optimization can really pay off. In addition to the bandwidth, gain, power and stability, numerous other requirements must be considered. In this example, power supply rejection ratios and preferential DC offset are included in the optimization trade-offs. Most of these goals are either inequality constraints that should be less or greater than a target value or line segment. There is one equality objective to ensure that the amplifier is free of any preferential DC offset voltage. Other measurements are monitored but not included as objectives.

Once measurements are defined, setting up the optimization objectives is very easy. As shown in ***Figure 3***, when choosing "Add an Optimization Goal," a form pops up displaying all the measurements. The user simply selects which measurement to include in the optimization session and chooses whether to make it greater, less than, or equal to a value (or range of values over a frequency or time range, if applicable). In this example, the optimization goals are evaluated using a variety of simulators:

Fig. 3 A pop-up form displays all the selections for choosing goals.

• For the DC operating conditions, including power and output offset voltage, the harmonic balance simulator is used.
• For the AC performance factors, including open- and closed-loop small-signal gain and phase as well as the positive/negative power supply ratios, the linear simulator is called.
• For the time-domain unit-step overshoot calculation, Synopsys' HSPICE transient analysis is executed.

Note that simultaneous optimization of goals from different simulators is a unique feature not offered in all circuit design tools.

Using experience and first principles, some time was spent to tune and refine an initial set of component values. With the touch of one button, all measurements are evaluated and, at the same time, those measurements associated with the optimization session are included in the overall cost function value. By defining the optimization goals with corner sweeps, the optimizer will ensure that the worst-case corner measurement is always considered during the session. This feature provides a form of design centering. In all, four HSPICE transient simulations and four DC and AC frequency-sweep simulations are run, taking about 20 seconds on a 1.4 GHz Pentium PC. Obviously, keeping simulation time to a minimum is an important factor in speeding up the optimization session.

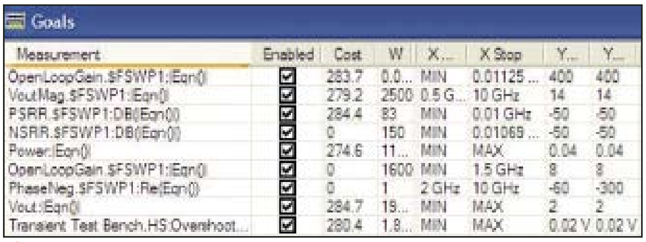
Listed below are the specific objectives to be considered during the optimization session, as shown in the Optimizer Form (see ***Figure 4***).
• The first Open-loop Gain objective is the amplifier low frequency open-loop gain (magnitude) that should be greater than 400.
• Vout Mag (a measure of stability) is the AC closed-loop gain peaking between 0.5 and 10 GHz that should be less than 14.
• PSRR is the positive power supply rejection ratio up to 0.01 GHz that should be less than –50 dB.
• NSRR is the negative power supply rejection ratio up to 0.01 GHz that must be less than –50 dB.
• Power is the amplifier DC power that must be less than 60 mW. However, to push for lower power, a very challenging 40 mW is targeted.
• The next Open-loop Gain objective is a measure of the Gain-bandwidth product and should be greater than 12 at 1 GHz.
• Phase Neg is the phase shift through the amplifier and should be less than 60° at 2 GHz and less than 300° at 10 GHz. This constraint is not actually required, but was added to keep the amplifier from becoming unstable. It will not be included in the trade-off analysis to come.
• Vout is the DC output voltage and a measure of the preferential offset voltage. It should be equal to 2 V, the input common mode voltage.
• Transient Overshoot (a measure of stability) is the pulse response output overshoot in the time domain and should be less than 0.02 V (~20 percent).

To ensure a successful optimization session, it is important that the user define realizable goals and constraints. There is nothing wrong with pushing the envelope, but setting

grossly unachievable objectives will only reduce the effectiveness of the optimizer. If the user finds that some of the targets are too aggressive, refining them during the optimization session is possible and can enhance the ultimate solution.

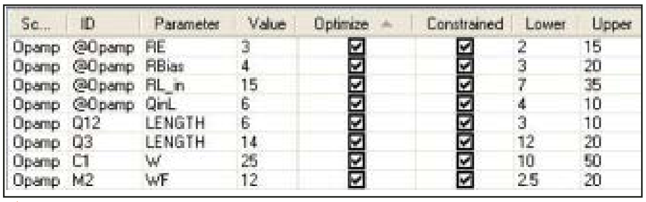
The amplifier optimization goals and constraints were set after running an initial set of measurements. Notice in the Optimizer Form that the "Cost" values are all about the same as a consequence of selecting the "Equalize Goals" command. When necessary, weights can and should be modified to increase or decrease the objectives' importance in the overall cost metric. When invoked, the optimizer will modify the design parameters to reduce the overall cost value. The cost value is a relative measure of goodness and is only pertinent when compared to other costs in the same session.

When dealing with a large number of requirements and design parameters, there should be no illusion that there exists only one best set of design parameters. There are a variety of component value combinations that can give similar results, and more importantly, defining what "best" means is usually a very subjective exercise. That is, meeting or exceeding the requirements as shown on a data sheet is very definitive. But, what if the DC power could be reduced significantly with only a marginal degradation in other performance factors. Would that be better? Only the specific system application for the amplifier can answer this question. Therefore, offering a variety of performance options to the system designer may be the best approach, and again, the optimizer is the best way to quickly generate these options.


Goals

Measurement	Enabled	Cost	W	X...	X Stop	Y...	Y...
OpenLoopGain.$FSWP1:Eqn()	☑	283.7	0.0...	MIN	0.01125 ...	400	400
VoutMag.$FSWP1:Eqn()	☑	279.2	2500	0.5 G...	10 GHz	14	14
PSRR.$FSWP1:DB(Eqn())	☑	284.4	83	MIN	0.01 GHz	-50	-50
NSRR.$FSWP1:DB(Eqn())	☑	0	150	MIN	0.01069 ...	-50	-50
Power:Eqn()	☑	274.6	11...	MIN	MAX	0.04	0.04
OpenLoopGain.$FSWP1:Eqn()	☑	0	1600	MIN	1.5 GHz	8	8
PhaseNeg.$FSWP1:Re(Eqn())	☑	0	1	2 GHz	10 GHz	-60	-300
Vout:Eqn()	☑	284.7	19...	MIN	MAX	2	2
Transient Test Bench.HS:Overshoot...	☑	280.4	1.8...	MIN	MAX	0.02 V	0.02 V

Fig. 4 The optimizer form "Goals" tab.



Sc...	ID	Parameter	Value	Optimize	Constrained	Lower	Upper
Opamp	@Opamp	RE	3	☑	☑	2	15
Opamp	@Opamp	RBias	4	☑	☑	3	20
Opamp	@Opamp	RL_in	15	☑	☑	7	35
Opamp	@Opamp	QinL	6	☑	☑	4	10
Opamp	Q12	LENGTH	6	☑	☑	3	10
Opamp	Q3	LENGTH	14	☑	☑	12	20
Opamp	C1	W	25	☑	☑	10	50
Opamp	M2	WF	12	☑	☑	2.5	20

Fig. 5 Design parameters selected for the optimization session.

At any time, the optimization session can be interrupted so that goals, measurements, design parameters, test benches and circuit topologies can be modified. The session can then be restarted from the last design state or any previously saved state. This ability to interact with and modify any aspect of the problem during the session is crucial to the effectiveness of the optimization. It offers the designer the flexibility to use his/her knowledge of the design to refine the problem and search to better the results.

Selecting Design Parameters and Setting Their Initial Values/Constraints

Intelligent selection of the goals and their weights/targets is only part of the path to a successful optimization session. Probably more important is the selection of the design parameters, their initial values and min/max constraints. Some optimization tools promote the fact that they can handle very large numbers of parameters without much insight as to their impact on the goals or their initial values. However, by simply throwing every design parameter with an arbitrary value into the mix, the optimization session is sure to be more time-consuming and unproductive. The optimizer solution described here can also handle large numbers of design parameters, and the algorithms available are very robust. Most can usually find a good solution from any reasonable starting point. Here again, it is the designer's knowledge of the problem that can best be applied to pick a thoughtful and manageable set of design parameters and their starting values. In IC circuit design, the selection of design parameters is made more interesting because some component values must "match" others, and some have only discrete choices. Defining "matched" component values is easily done by creating a single variable for those values. The variable is then defined as an optimization parameter. To define a discrete parameter, the component value is simply made

TABLE I
OPTIMIZATION SESSION RESULTS

Objective	*Target Value*	*Initial Value*	*Low Power* 50 iterations *Value*	*%**	*Low Power* 100 iterations *Value*	*%**	*Low Power* 300 iterations *Value*	*%**	*High Speed* 300 iterations *Value*	*%**
Overshoot (V)	0.02	0.02	0.02	0	0.024	–20	0.021	–5	0.025	–25
Peaking (vout/vin–closed loop)	14	13.4	13.6	3	14.5	–4	13.9	1	15.7	–12
VOUT (V)	2	1.88	1.95	4	1.97	5	1.92	2	1.97	5
PSRR (dB)	–50	–55	–50	0	–49	–2	–53	6	–47	–6
NSRR (dB)	–50	–60	–69	38	–58	16	–60	20	–52	4
Open-loop gain (vout/vin)	400	387	333	–14	402	4	500	28	405	5
Gain*Bandwidth (GHz)	12	9	11.2	18	11.4	20	11	17	15	**50**
DC power (W)	0.06	0.06	0.05	17	0.045	25	0.039	**35**	0.061	–2

*The percent improvement (degradation if negative) over the **Initial Value** (or the **Target Value** if it is worse)

into an integer variable and the optimization algorithm then recognizes it as such. Two of the 10 built-in algorithms available, Pointer and Random, will support combined discrete and continuous variable optimization. For this operational amplifier example, the design parameters selected for the optimization session are shown in ***Figure 5***, where

- RE is the length of the level-shifter matched resistors whose values help define the voltage and current levels of the level-shifter, that is, power, gain and offset voltage.
- RBias is the length of the bias resistor defining the currents throughout the amplifier, that is, power, gain, gain-bandwidth and stability/phase shift.
- RL_in is the length of the input stage matched load resistors that affects gain, level-shifter voltages and phase shift.
- QinL is the discrete matched parameter for the input stage device sizes whose emitter resistances and parasitic junction capacitors help determine gain, bandwidth and stability/phase shift.
- Q3_LENGTH is a discrete parameter for the input stage current source device size that determines the input stage current and partially determines its transconductance, that is, gain and power.
- Q12_LENGTH is a discrete parameter device size for the gain stage transistor whose current density, parasitic capacitance and emitter resistance is central in the calculation of gain, gain-bandwidth and stability.
- C1_W is the gain stage compensation capacitor width that determines the roll-off capacitor value, that is, gain-bandwidth product and stability.
- M2_WF is the finger width of the PMOS device that determines the gain stage load current source value, that is, gain and power.

There are numerous other component values that could be included, but most of them have only second-order impact upon the goals. After setting the initial values, some manual interactive tuning was applied to bring the design to a reasonable state that comes close to meeting the critical requirements. However, when dealing with more than a few requirements and design variables, it is very difficult to find the best solution. This is where optimization is best applied.

Constraining the design parameter excursions is always a good idea. Keeping capacitor and resistor values above zero and less than what the semiconductor process can deliver is probably obvious. But it is also good practice to limit the range of the design parameters even further to keep the optimizer from considering cases that are clearly unacceptable.

THE OPTIMIZATION SESSION

Selecting the Algorithm and Testing the Design Space

Now that the goals, weights, design parameters and constraints are defined, the optimizer is ready to run. Since this amplifier has discrete design parameters, either the Pointer or Random algorithm can be applied. The Pointer algorithm is chosen because it is typically more efficient for nonlinear problems with costly simu-

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Gali 1	DC-8000	12.7	12.2	4.5	27	108	40	3.4	.99
Gali 21	DC-8000	14.3	12.6	4.0	27	128	40	3.5	.99
Gali 2	DC-8000	16.2	12.9	4.6	27	101	40	3.5	.99
Gali 33	DC-4000	19.3	13.4	3.9	28	110	40	4.3	.99
Gali S66	DC-3000	22	2.8	2.7	18	136	16	3.5	.99
Gali 3	DC-3000	22.4	12.5	3.5	25	127	35	3.3	.99
Gali 6F	DC-4000	12.1	15.8	4.5	35.5	93	50	4.8	1.29
Gali 4F	DC-4000	14.3	15.3	4.0	32	93	50	4.4	1.29
Gali 51F	DC-4000	18.0	15.9	3.5	32	78	50	4.4	1.29
Gali 5F	DC-4000	20.4	15.7	3.5	31.5	103	50	4.3	1.29
Gali 55	DC-4000	21.9	15.0	3.3	28.5	100	50	4.3	1.29
Gali 52	DC-2000	22.9	15.5	2.7	32	85	50	4.4	1.29
Gali 6	DC-4000	12.2	18.2	4.5	35.5	93	70	5.0	1.49
Gali 4	DC-4000	14.4	17.5	4.0	34	93	65	4.6	1.49
Gali 51	DC-4000	18.1	18.0	3.5	35	78	65	4.5	1.49
Gali 5	DC-4000	20.6	18.0	3.5	35	103	65	4.4	1.49
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lation run-times. Before the optimizer is let loose to run a lengthy session, it is advisable to see how the design improves over a small number of iterations (25 to 50, for instance). If no improvement is seen, it should be run a little longer, and if there is still no change, it may be necessary to modify the setup by changing weights, goals or design parameters. It may even help to add or eliminate goals or design parameters. In most cases, the user will see some measurable improvement and the optimizer can then be run for a much larger number of iterations to realize a much better design.

Running the Optimizer

The optimizer is run for 50 iterations and the results analyzed. After 50 iterations, the cost function is improved substantially. Once it seems that things are set up properly, the optimizer is run for a total of 100 iterations. This takes about 30 minutes. At this point, the objective weights were refined to improve power at the expense of some of the other requirements. Also, some design parameters were disabled after they were seen to diminish in importance as the session proceeded. This process continued with incremental 100 iteration runs/refinements to understand and generate options between the overall trade-offs. This interaction is vital to maximize the optimization. In total, the session takes several hours, but the designer can be confident that the design space trade-offs have been comprehensively covered and the performance of the amplifier has been pushed to its limits.

Results of the Optimization Session

Table 1 shows the results of several different optimization sessions for the operational amplifier. The worst-case objectives were measured at 50, 100 and 300 iterations with emphasis on low DC power. Another 300 iterations with emphasis on high speed or gain-bandwidth product were then taken. As can be seen, the optimizer was able to deliver significant improvement in the most critical specifications, while maintaining reasonable values for the others.

CONCLUSION

Although many EDA companies offer optimization, the technology has not progressed very rapidly in the analog circuit design world and most tools are limited by poor ease-of-use, tedious setup and slow performance. This tutorial has demonstrated an easy-to-use, fast and interactive optimization solution that works very effectively for analog and RF applications. The solution discussed in this article provides a highly efficient alternative to the traditional process that employs multiple optimization algorithms and provides a choice in methods that can be applied depending upon the problem definition and breath of the design space to be explored. ■

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APPENDIX A
DESCRIPTION OF AVAILABLE OPTIMIZATION ALGORITHMS

The Pointer Robust Algorithm

The Pointer optimizer combines the power and robustness of four widely used and accepted search methods: linear simplex, downhill simplex, sequential quadratic programming and genetic algorithm (which includes an automated training feature).

This algorithm is probably the best general method for time-consuming nonlinear circuit simulations. It is a proprietary "smart" optimizer that can explore beyond the local optimum. It uses built-in intelligence to actively switch between the four different methods while the optimization is in progress.

Random (Local)

Random steps from an initial starting point in the search space. The random optimizer is probably the best optimizer to use when the number of variables is large, because it operates almost as efficiently with a large number of variables as with a small number and requires a minimal number of functional evaluations per iteration.

Random (Global)

This optimizer randomly selects trial points from the entire solution space in search of the optimum. This method should only be used when there are just a few variables to be optimized and the error function is highly irregular or discontinuous.

Gradient Optimization

The Davidson-Fletcher-Powell optimizer (also known as the Fletcher-Powell method) is loosely called a gradient method; precisely, it is a quasi-Newton optimizer. It is the most powerful, per iteration, of the three optimizers, but requires a large number of functional evaluations per iteration. It is the best optimizer to use for simple circuits with straightforward requirements.

Simplex Optimization

The downhill simplex search (based on the Nelder-Meade optimizer) is relatively slow but very robust. A nice property of the simplex optimizer is that is follows difficult contours in the error function quite well, albeit slowly.

Genetic Algorithms

The chromosomes used for the optimization problem are the continuous design parameters that define the search space. Each gene is represented by a single scalar value in the set. The typical combinatorial optimization versions of genetic algorithms create new points in space from two previous points in the space, by gene crossover and mutation. There are two mutation options: Gaussian Mutation, where, for each parent gene, a number is generated from a normal distribution using the parent as a mean for the distribution; and Uniform Mutation, where, in the second method, a gene is generated using a uniform random distribution between the two parent gene values.

Simulated Annealing (Simplex)

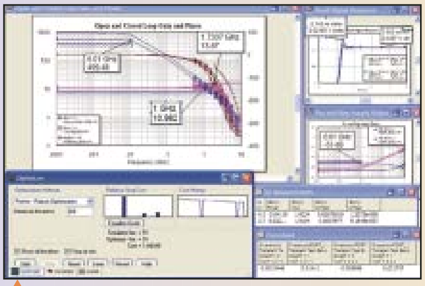
Simulated Annealing is used in conjunction with the downhill simplex method discussed previously. The Simulated Annealing method is incorporated into the downhill simplex method by adding a small temperature dependent probabilistic deviation to the cost of each point in the simplex.

Simulated Annealing (Local)

Simulated Annealing is used in conjunction with the local random optimization method discussed previously. The Simulated Annealing method is incorporated into the random search method by adding a small temperature dependent probabilistic deviation to the cost of each evaluation.

Session Screenshot

Figure A1 shows a view of the project window in the Analog Office™ circuit design software from Applied Wave Research (AWR®). Most of the measurements and the Optimizer form are displayed during the optimization session. As shown in the AC response graphs, the open-loop gain and phase along with the closed-loop gain are plotted over for the power supply and load capacitor corners. Notice that the optimization constraints are displayed as hashed lines on those measurement graphs that apply.



▲ *Fig. A1 Project window in the Analog Office™ circuit design software.*

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	RO3000® Series	RO3000® Series
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Highlights from the First Radio and Wireless Symposium

Jennifer DiMarco and Frank Bashore
Microwave Journal *staff*

January is a very nice time to be visiting San Diego, CA, as the 2500 attendees of the first annual IEEE Radio and Wireless Symposium (RWS 2006) found as they came in from various parts of the US and overseas. Winter tends to be long and cold for many of us and the all too short, week-long event in sunny southern California provided an enjoyable respite from the cold and snow.

The newest of IEEE MTT-S symposiums featured a comprehensive technical program with 119 technical presentations in 24 interesting sessions spread over Tuesday, Wednesday and Thursday plus workshops on Sunday and Monday and short courses on Saturday and Friday. There were also two panel sessions and 38 poster sessions. In all over 750 engineers signed up for the technical program and many of the technical sessions were at capacity.

The daunting task of putting together a new symposium and exhibition fell squarely on the shoulders of this year's general chair, Fred Schindler, and his very capable staff. The technical program is an outgrowth of the older RAWCON technical symposium with the addition of the 6th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems conference and the Power Amplifiers for Communications meeting, and has encompassed disciplines from both MTTS and the IEEE Communications Society.

Kicking off the symposium was a traditional welcoming by the general chair,

an overview of the technical symposium by Mohammad Madihian, technical program chair, and an inspiring plenary talk by Dr. Andrew Viterbi, a co-founder of Qualcomm Inc. The result of the week-long program was a focus on wireless systems, applications and technologies from both a component and system design viewpoint.

As has been the tradition with the larger IMS Symposium, this year to be held in June in San Francisco, CA, there was also a commercial exhibition to showcase new products and technologies from a number of companies in the US and abroad. This being the first event, the exhibition was modest with 125 companies exhibiting. The companies were eager to display their newest product and services, a sampling of which follows, with apologies to the companies that are not mentioned.

Agilent Technologies Inc. showcased its CSA spectrum analyzer, new series 8000 Infiniium Scopes and VSA software, component test solutions, cellular R&D solutions and the Bluetooth/ZigBee/WLAN one-box tester. These products for wideband systems accelerate the design of high speed wireless devices and networks. Agilent's EEsof EDA Division announced a plan to expand its EDA product portfolio to include full 3D electromagnetic (EM) simulation. The new product is expected to transform the way 3D EM software is priced and offered to RF and microwave designers. The announcement comes after the recent acquisition of Eagleware-Elanix, a leading supplier of easy-to-use, PC-based circuit and system simulation software.

Analog Devices Inc. extended its portfolio of radio frequency integrated circuits with a new analog-control variable-gain amplifier that offers good linearity over a broad frequency range for wireless infrastructure applications, such as cellular base station radio transceivers. The model AD8368 is optimized to maintain dynamic range of base station radio transceivers, ensuring that both weak and incoming call signals are effectively handled and maintained.

Anritsu announced the ML2490A series peak power meters that feature industry-best bandwidth and rise time to conduct highly accurate pulse measurements on rapid rise time radar signals and complex new modulation techniques used in 4G applications and wireless systems such as WiMAX. Also introduced at RWS was the MT8860B WLAN test set, a protocol-based single-instrument test solution for analyzing performance of 802.11b/g devices and consumer products.

AR Worldwide Modular RF has designed and built a custom amplifier module for the emerging wireless access market. The model KMS1070 was created in 45 days to meet a client's selected frequency band and a very demanding linearity specification. The KMS1070 is a 3.4 to 3.7 GHz solid-state power amplifier module for the wireless broadband network. This 20 W, 43 dBm output linear power amplifier offers a scaleable gain of 20 to 50 dB and is designed to meet WiMAX 802.16d specifications. It can be modified to meet various types of OFDM or NPR requirements.

Cascade Microtech displayed its WinCal 2006 software that addresses the testing challenges brought on by

the increase in the volume of complex, high speed semiconductors designed and tested for use in mobile communications products. Also on display at the Cascade booth was the eVue™ digital imaging system that enables dramatic productivity gains in semiconductor wafer navigation and testing. More recently, the company announced that its Pureline™ wafer probing systems have been purchased by five of the world's top 20 semiconductor manufacturers in the United States, Asia, Japan and Europe. Cascade also featured Pureline wafer probing systems that allow semiconductor manufacturers to model, characterize and test the latest generation of integrated circuits required for today's demanding applications.

With its seventh-generation high voltage (HV7) RF LDMOS technology, Freescale Semiconductor has achieved the RF power transistor performance required for use in WiMAX base stations operating in the 3.5 GHz band. Freescale claims this achievement marks the first time RF laterally diffused metal oxide semiconductor technology from any manufacturer has met these challenges.

Hittite Microwave Corp. showcased a montage of new products including the model HMC-C026, a GaAs MMIC distributed power amplifier connectorized module that is ideal for military EW/ECM, space, test equipment, wideband telecom, microwave radio and industrial applications from 2 to 20 GHz. This high dynamic range power amplifier module offers a midband noise figure of only 3 dB, with +25 dBm output power at 1 dB gain compression. This module features 29 dB of

gain, allowing it to replace two or more amplifier stages in applications where high gain is required.

Two GaAs PHEMT low noise MMIC amplifiers were also on display. These LNAs are optimized for specific application frequency bands with little or no external matching, and are footprint compatible such that a single PC board design can be used to implement either part number. The model HMC376LP3 and model HMC382LP3 amplifiers operate from 700 to 1000 MHz and 1700 to 2200 MHz, respectively.

Also on display were model HMC586LC4B and model HMC587-LC4B, wideband GaAs HBT VCOs that cover 4 to 8 GHz and 5 to 10 GHz, respectively. Output power and phase noise performance are good over temperature due to the monolithic construction of the oscillators. The Vtune port accepts an analog tuning voltage from 0 to +18 V. These wideband VCOs combine the attributes of ultra small size, low phase noise, low power consumption and wide tuning range.

Keithley Instruments Inc. introduced its new model 2910 RF vector signal generator that offers capabilities and ranges making it ideal for production testing of today's sophisticated mobile handsets as well as for applications such as communications research, the testing of mobile communications infrastructure, RFICs and wireless connectivity devices. The model 2910's continuous frequency range of 400 MHz to 2.5 GHz spans key mobile wireless bands.

Lark Engineering Co. featured its family of surface-mount combline filters from 5 to 15 GHz, with a bandwidth from 3 to 20 percent and exceptionally low insertion loss.

M/A-COM was displaying model MAAPSS0076, a RoHS-compliant, DECT power amplifier for applications that require dual power modes, high gain and small size at a low cost. Also on display was the model MAATSS0022, a RoHS-compliant five-bit serial controlled attenuator for applications that require high accuracy and monotonic performance at a low cost. The model TU-3840 wideband ELINT tuner is designed for use in high end signal processing military applications and is based on the company's successful, SEI-certified, SMR-3822 RF microwave sweeping receiver technology. Model MA4-PBL027 HMIC silicon beam lead PIN diode is the most recent addition to the beam lead PIN diode group.

Mimix Broadband showcased several products while highlighting model CMQ1432, a 32 dBm power amplifier module that operates from 13.75 to 14.50 GHz. The new PA features a low cost 4x4 mm, 24-pin plastic QFN package, 31 dB gain and 32 dBm saturated output power, and is RoHS-complaint and self-contained.

Peregrine Semiconductor featured its 75 ohm UltraCMOS™ switches that provide good isolation, linearity and ESD tolerance for today's most demanding CATV and DTV applications. Also on display were UltraCMOS phase-locked loops, prescalers and mixers that are manufactured on the company's proprietary UltraCMOS™ silicon-on-sapphire process technology. These products draw from many years of high performance RF CMOS and mixed-signal IC experience. Wireless UltraCMOS switches feature high isolation, high ESD tolerance and low insertion loss, providing an optimal solution for most any wireless application.

Radio Waves Inc. announced a breakthrough in microwave antenna technology with a new generation of the company's HP3-11 three-foot high performance dish. The new HP3-11 provides FCC Cat A performance for the 11 GHz band in a three-foot dish. Previously network designers and operators were required to utilize a four-foot dish for links to be considered Cat A compliant. By utilizing a three-foot dish, network planners can easily pass local zoning rules in regards to antenna size on building structures.

RF Micro Devices Inc. announced the commercial launch of its complete POLARIS 2™ TOTAL RADIO™ Module solution, which is comprised of a cellular transceiver module and a cellular transmit module for handsets operating on the GSM/GPRS and GSM/GPRS/EDGE networks. The performance, size and cost advantages of the POLARIS 2 TOTAL RADIO Module solution enable handset manufacturers to quickly and cost-effectively introduce smaller, more feature-rich handsets capable of delivering the advanced levels of functionality and services for today's high data-rate networks.

Rohde & Schwarz introduced the R&S SMA100A analog signal generator, which provides good signal quality and short level and frequency-setting times in a compact footprint that requires only two 19" rack units. The R&S SMA100A delivers extremely pure output signals over its operating frequency range of 9 kHz to 3 GHz. Also on display was model R&S ZVA24, the company's new flagship

vector network analyzer, which is available with either two or four test ports and offers a measurement frequency range of 10 MHz to 24 GHz.

Skyworks Solutions Inc. announced its highly innovative CMOS switches for satellite receiver applications that are gaining significant market traction and have commenced volume production in support of several customers throughout Asia and Europe. The model SKY13264-340LF and model SKY13272-340LF, which were first launched in June 2005, offer high isolation direct broadcast satellite complementary metal oxide semiconductor switches that deliver higher levels of integration, are easier to implement and offer customers a lower cost alternative.

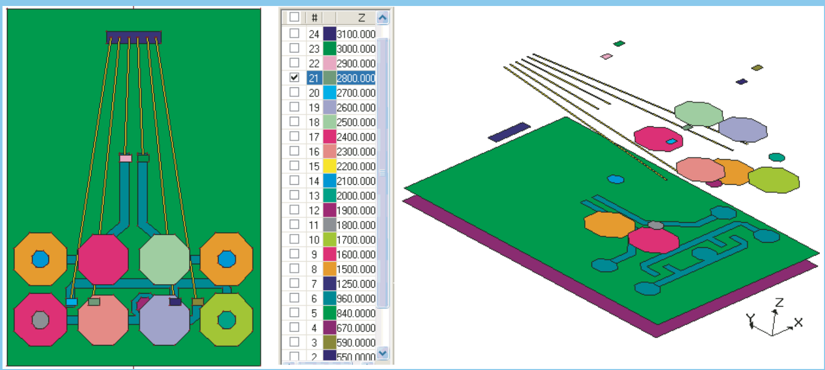
Southwest Microwave featured its SSB family of high density interconnect solutions, which are designed for microwave and digital applications.

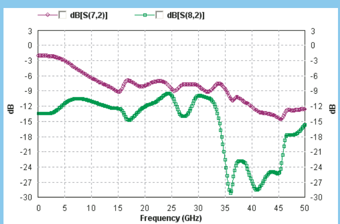
TriQuint Semiconductor Inc. introduced a high power antenna switch for CDMA applications. The new product, TQP4M3019, is in a 2×2 mm, 12-lead STSLP package. The part, in single-pole, triple-throw (SP3T) configuration, provides good cross-modulation and isolation performance while exhibiting low insertion loss in all frequency bands including PCS, cellular and GPS.

Again, our apologizes for omitting any company or its new products. However, space constraints limit our ability to list everyone.

For a first time event the technical program appeared to be a definite success and the many attendees went home with much new information. The industry exhibition was lightly attended and will take more time to gain the attendance and momentum of its bigger sister IMS. However, valuable contacts were made and worthwhile discussions were had by many of the participants, laying the groundwork for a warm weather winter event that will ultimately be another valuable interchange of products and technology.

Next year RWS 2007 will be in Long Beach, CA, January 6 to 12. We hope to see you in June in San Francisco for IMS 2006 and again in January in Long Beach. ■

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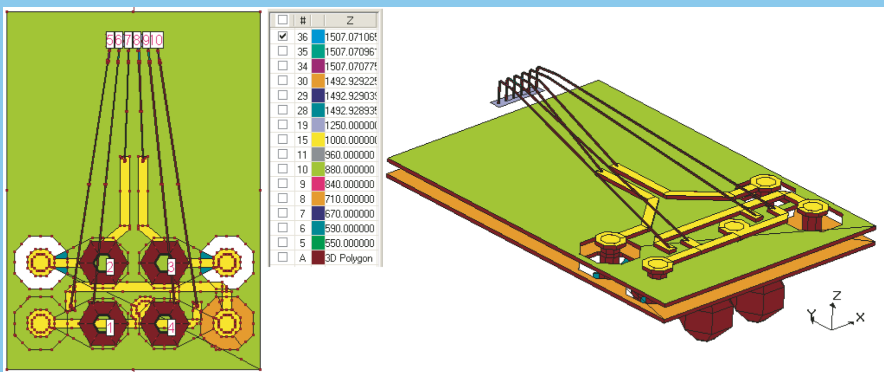
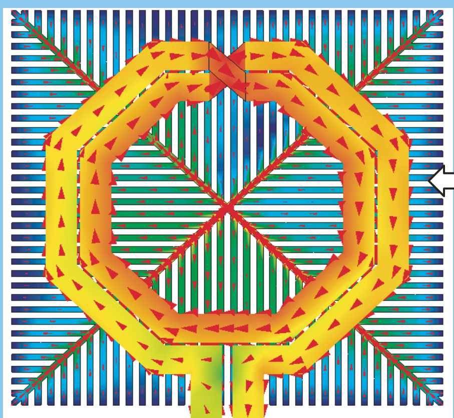
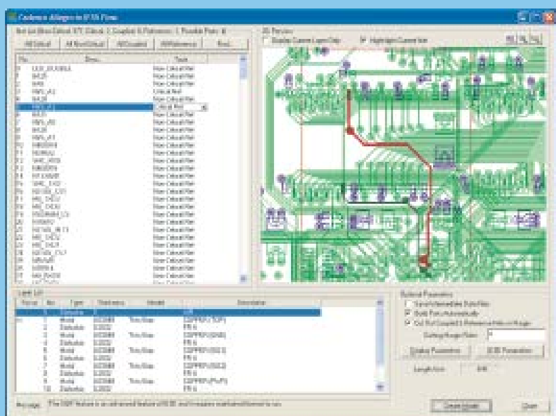






WCDMA Front-end Modules and Their Critical Role in 3G Wireless Handsets

A January 2006 survey from the GSA (Global mobile Suppliers Association) confirmed strong growth and market acceptance of WCDMA as the leading global 3G technology. The number of 3G/WCDMA networks delivering commercial services was then pegged at 100 in 42 countries, an increase of 22 networks during 2005. A wide variety of WCDMA/HSDPA terminal devices have been announced in the market, 186 models from 26 suppliers, with 70 models launched just in the last six months. The survey also identifies 57 operators now serving customers, or in the process of deploying combined WCDMA and EDGE networks.

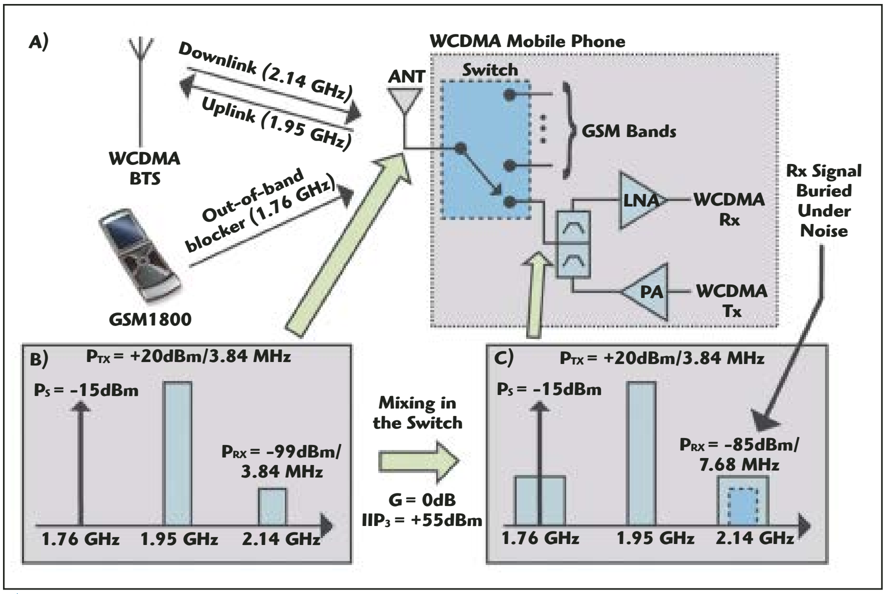
Initial growth has been primarily focused on single-band WCDMA (IMT/UMTS) 2100 plus GSM/EDGE, targeting the European and Asian marketplaces. Following in short order, carriers will release dual-band WCDMA-850 and WCDMA-1900 networks that will target the US.

To ensure service continuity, both WCDMA and GSM/EDGE must be incorporated into the handset terminal. Multi-mode/multi-band integrations into a single terminal will create both opportunities and challenges for the handset designer.

With the success of Motorola's Razr® handset in 2005 (more than 12 million handsets sold so far), a model for the future has been established: ultra-thin, feature-rich, lightweight and with no external antenna. The Razr has set the bar higher than ever before, challenging module/component suppliers to offer the handset designer highly integrated products that provide the smallest possible footprint in the thinnest package available. Size has therefore taken center stage, and as the market had demonstrated with all things wireless so far, smaller is bigger when it comes to sales and satisfied customers.

The integration and efficiency requirements of the WCDMA RF front-end require key technologies, including the ability to optimize components to transceiver and baseband while being as 'miserly' with power conservation as possible. All this has to come in ever-shrinking package form factors and with platform concepts in mind, design cycle time (and reducing it) comes near the top of every module shopper's wish list.

TRIQUINT SEMICONDUCTOR
Orlando, FL



▲ *Fig. 1 Example of out-of-band blocking (intermodulation) for a WCDMA handset.*

Addressing the technical challenges of the new multi-mode WCDMA handset, highly integrated WCDMA front-end modules (FEM) combine the GSM SAW Rx filters, a multi-mode switch and transmit harmonic filters into an ultra-small footprint with a very low profile (5.4 × 4.0 × 1.1 mm^3).

A key component of the WCDMA FEM is front-end switching technology, which in earlier generation GSM wireless phones has historically been dominated by PIN diode applications. PIN diodes have demonstrated longevity, providing handset designers with a simple solution at the lowest possible cost. However, PIN diodes have now reached their limitations and will struggle to provide competitive switching solutions that can meet the technical demands of the WCDMA (3G) handset (size and current consumption requirements, for example).

PIN diodes must inevitably give way to new switching technologies. However, the new technology must meet the demanding requirements of the 3GPP technical specification if they are going to take a leadership role and displace PIN diodes. The primary challenges in meeting the 3GPP specification in this area that demand attention include:

- WCDMA linearity (out-of-band blocking)
- GSM linearity (harmonics)
- Insertion loss and isolation performance.

WCDMA LINEARITY (OUT-OF-BAND BLOCKING)

A switch must address the out-of-band blocking requirements in order to address WCDMA linearity needs. Designers critically examine the various discrete components or the antenna switch module (ASM), or the front-end module (FEM) located between the antenna and the transceiver/baseband when looking at linearity issues. They are concerned primarily with out-of-band (third-order) linearity performance. The third or higher out-of-band interferer arises to a mixing effect of the transmitted WCDMA signal with an external blocker signal (see ***Figure 1***). The mixing effect in this case is producing an interfering signal in the receive band of the relative transmitted channel. This in turn creates distortions in the receiver channel passband (intermodulation products are created when two or more frequencies mix in nonlinear devices).

The third or higher intermodulation measurement is used to define the receiver faculty to treat the desired signal even in the presence of any unwanted signals in its assigned frequency range.

WCDMA receiver RF tests use coded bit-error rate (BER) as the performance metric to assess specification compliance. To pass the receiver tests, a coded BER of < 0.1 percent is required under a range of test conditions designed to stress sensitivity, linearity and selectivity of the receiver. The out-of-band requirement is defined only implicitly by the need of the frequency-division duplexing (FDD) receiver to pass out-of-band blocking de-sense tests in the presence of a large transmit leakage signal at the antenna. From the WCDMA specifications, four blocking regions exist that can produce in-channel products when mixed with the transmitter leakage signal.

Based on industry standards and the authors' own calculations, it has been determined that the out-of-band intermodulation product produced by the switch should not exceed –103 dBm with the conditions specified in ***Table 1***. This –103 dBm level does not take away from any of the 24 possible exceptions at the final system level test allowed in the 3GPP specification. The WCDMA port is also terminated with a high impedance duplexer and the blocker signal will be presented to the antenna at an unknown phase. Therefore, the handset designer must insure that the FEM meets the performance in Table 1 across all possible phases. Switch IM3 linearity performance is extremely phase dependent, as seen in ***Figure 2***.

Phase must be considered when determining the linearity of the multi-mode switch because this is the only certain method to meet the 3GPP out-of-band blocking requirements. The plot demonstrates the possible variability of IM3 performance over phase. It is shown that the FEM is meeting the previously stated requirement. Another important point is to identify the differences between a two-tone IM3/IIP3 test as compared to a standard single-tone IIP3 test condition. The switch IP3 performance is used to determine the in-band linearity, but the IP3 performance should not be used to determine whether the antenna switch meets the selectivity requirement or provides adequate blocking characteristics. The IP3 performance can only be used for reference purposes and does not correlate into IM3 selectivity. Therefore, it is highly recommended to quantify the out-of-band linearity of a switch by measuring the exact modulation product found in the Rx-band (IM3) or by the IIP3 through a two-tone measurement. A switch that meets the out-of-

TABLE I

PERFORMANCE REQUIRED TO INSURE COMPLIANCE TO THE 3GPP TECHNICAL SPECIFICATION

Parameter	Conditions	Frequency	Maximum Level
Intermodulation product power in Rx-band	P_{int} = –15 dBm, injected at the antenna P_{tx} = +20 dBm measured at the antenna **UMTS:** F_{int} = 1730 to 1790 MHz F_{tx} = 1920 to 1980 MHz **WB850:** F_{int} = 779 to 804 MHz F_{tx} = 824 to 849 MHz **WB1900:** F_{int} = 1770 to 1830 MHz F_{tx} = 1850 to 1910 MHz	Intermodulation product (P_{rx}) in the Rx-band measured at the antenna: **UMTS:** P_{rx}: 2110 to 2170 MHz **WB850:** P_{rx}: 869 to 894 MHz **WB1900:** P_{rx}: 1930 to 1990 MHz	–103 dBm

band linearity standard will inherently meet the in-band linearity requirements.

GSM LINEARITY (HARMONICS)

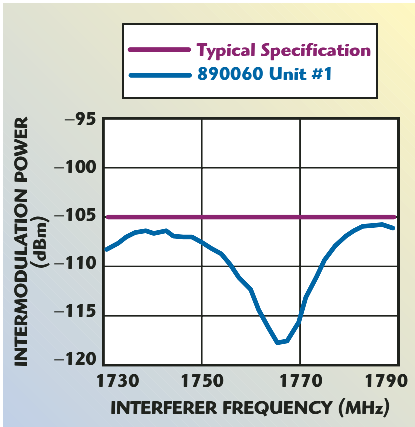
Just as the multi-mode WCDMA phone must conform to the 3GPP specification for WCDMA, its GSM linearity (harmonics) must continue to meet ETSI technical standards. While advanced switching technologies struggled in years past with GSM harmonic performance, many technology advancements have been made to overcome previous challenges. As seen in ***Figures 3*** and ***4***, the TriQuint FEM has overcome and meets all GSM harmonic requirements.

INSERTION LOSS AND ISOLATION PERFORMANCE

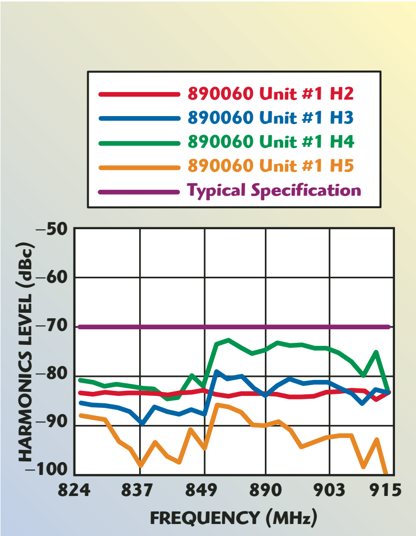
Finally, while WCDMA and GSM linearity are of utmost importance, one cannot overlook the need for lower insertion loss, increased band-to-band isolation, $2f_o$, $3f_o$ Tx harmonic filtering and Rx attenuation. While many trade-offs are needed to meet the WCDMA 3GPP specification, insertion loss cannot be compromised. 3G phones will include as many as twelve different frequency bands, requiring improved insertion loss and isolation. Continued integration of the baseband and transceiver requires improved Rx attenuation performance from the SAW filters as well. New switch, Rx SAW and Tx filtering technology have allowed FEMs to meet the linearity requirements stated above while providing competitive RF performance, as seen in ***Table 2***.

All FEM modules must include switch technology capable of meeting WCDMA and GSM/EDGE linearity performance while maintaining the lowest insertion loss and highest isolation performance. Integration of the four GSM Rx SAW filters is critical to achieving the highest level of integration and providing the smallest footprint while targeting the lowest height profile possible. Highly integrated FEMs can only be achieved through the advancements of SAW filter and module packaging technology.

Meeting the demands of WCDMA customers is an opportunity that will continue to challenge incumbent RF suppliers. To that end, TriQuint Semiconductor has a wide range of modules that address the specific needs of WCDMA and hybrid 'WEDGE' handsets that are highly integrated, compact and designed around the stringent requirements of the new 3G standard.



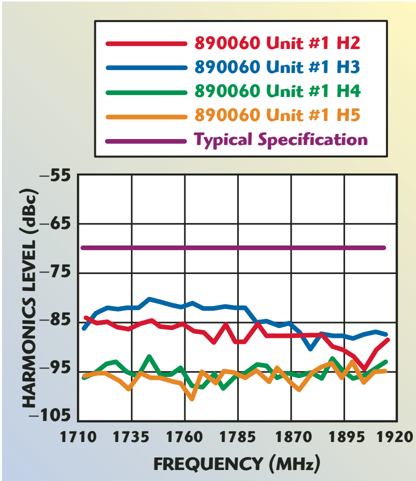
▲ *Fig. 2 Third-order intermodulation power as a function of interferer frequency for the 890060 WCDMA FEM (transmit power = 20dBm; interferer power = -15dBm).*



▲ *Fig. 3 Harmonics within the low band of the 890060 WCDMA FEM.*

Key components for any supplier seeking to satisfy the needs of WCDMA handset manufacturers should include:

- A single-band WCDMA FEM plus quad-band EDGE GSM-850/900/1800/1900



▲ *Fig. 4 Harmonics within the high band of the 890060 WCDMA FEM.*

- A dual-band WCDMA FEM plus quad-band EDGE GSM-850/900/1800/1900
- Transmit modules that include a WCDMA multi-mode switch, Tx harmonic filtering and the quad-band GSM EDGE PA
- WCDMA PA+duplexer modules that integrate the WCDMA PA with the WCDMA duplexers — PA+duplexer modules offer another level of integration that optimize the performance of the PA together with the duplexer.

The new WCDMA front-end modules are part of a larger portfolio of products optimized for the transceiver to baseband that are designed for future 3G slim-line, compact multi-mode/multi-band mobile devices. Additional information may be obtained via e-mail at bleonard@tqs.com.

TABLE II

FEM PERFORMANCE REQUIREMENTS

	Target (Typical) Performance
GSM-850/900 Tx	
Insertion loss (dB)	1.1
2fo attenuation (dB)	30
3fo attenuation (dB)	30
Tx to Rx isolation (dB)	25
GSM-1800/1900 Tx	
Insertion loss (dB)	1.2
2fo attenuation (dB)	30
3fo attenuation (dB)	30
Tx to Rx isolation (dB)	25
WCDMA Tx/Rx	
Insertion loss Tx (dB)	0.8
Insertion loss Rx (dB)	0.9
GSM-850 Rx insertion loss (dB)	2.6
GSM-900 Rx insertion loss (dB)	2.6
GSM-1800 Rx insertion loss (dB)	2.7
GSM-1900 Rx insertion loss (dB)	3.0

TriQuint Semiconductor, Orlando, FL (407) 886 8860, www.triquint.com.

RS No. 302

ROBOTIC COMPUTER-AIDED TUNING

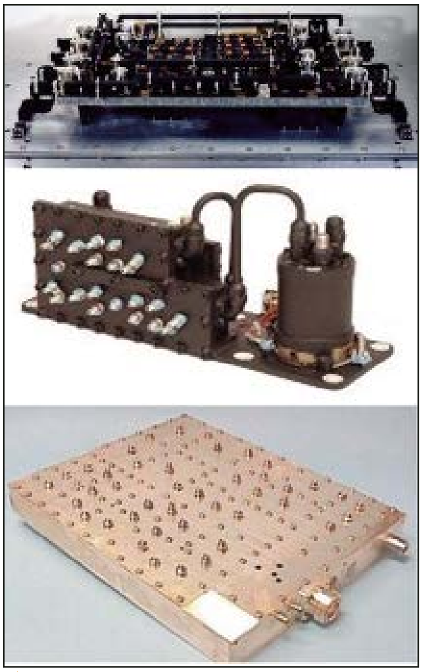
COM DEV Ltd. uses a RoboCAT (Robotic Computer-aided Tuning) automation system to achieve scaleable capacity, increased product consistency, in-line quality assurance, and reduced schedule and cost. ***Figure 1*** shows a RoboCAT system at work at COM DEV. The company is the world's leading supplier of filters, multiplexers and switches for communications satellites (see ***Figure 2***). For more than twenty years, the company has made significant investments in its software design tools and RF performance simulation capability. These tools have been validated on satellite hardware and have proven to be so precise that extremely demanding devices can now be machined directly for space flight production without the need for a costly, time-consuming breadboard stage. Still, final tuning is required to remove the effects of machining tolerance and, to a smaller extent, simulation inaccuracies. RoboCAT addresses this challenge with a combination of advanced automated tuning algorithms and clever automation tools.

Fig. 1 RoboCAT system at COM DEV.

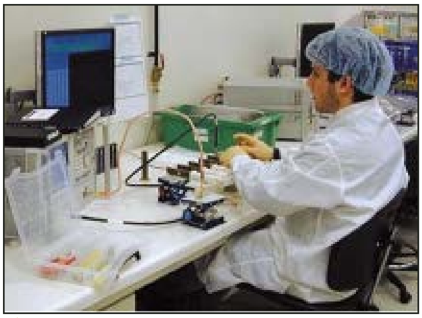
The final tuning stage has traditionally been an unpredictable bottleneck in the production of high frequency precision filters and multiplexers. RF filter tuning is a learned skill, and new hires require many months or years to become proficient at tuning even the simplest devices. Among experienced tuners there is a wide variation in the speed at which they are able to produce finely tuned hardware, as well as in their ability to tackle sensitive hardware. Therefore, device tuning is a potential source of schedule and cost risk, as well as an impediment to rapid changes in production capacity.

Computer-aided tuning (CAT) software was first deployed on the COM DEV production floor in 1995, and was used to augment manual tuning of satellite multiplexers. With CAT, the technician was guided through the tuning process with instructions on which screws to adjust and how far to turn to achieve optimal filter performance. CAT quickly became the tuning standard for the multiplexer product line and had an immediate impact on reducing cost and cycle time. The original software has been enhanced and refined since then, and is still being used on many product lines today.

COM DEV LTD.
Cambridge, Ontario, Canada



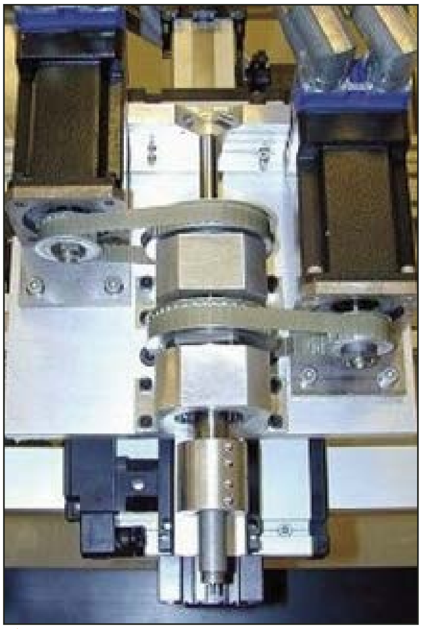
▲ *Fig. 2 COM DEV hardware for space- and ground-based applications.*



▲ *Fig. 3 A tuner uses CAT to tune a six channel MUX.*

The introduction of CAT enabled the company to decrease the skill level needed for tuning its most complex subsystems and allows multiple technicians to be involved with tuning a single device. Previously, a single technician was assigned to the task as the techniques employed by each tuner may be incompatible with those of the others. With CAT guiding the tuning process, technicians are able to hand-off a tuning task at any time, running multiple shifts if required to meet accelerated delivery requirements (see ***Figure 3***). Computer-aided tuning replaces the "black art" of filter tuning with a systematic approach for improved operational efficiency and productivity.

While the CAT system vastly improves the predictability of tuning, it is still a manual process that is not well suited to the higher volume pro-



▲ *Fig. 4 Coaxial screw/nut driver to handle standard tuning screws and lock nuts.*

duction requirements of the wireless marketplace. To deal with it's higher volume product lines, COM DEV has developed a custom tuning robot capable of enacting fine tuning screw adjustments.

The company employs a development strategy based on Design For Manufacturing, Assembly, Integration and Test (DFMAIT). In this philosophy, both the product and relevant processes are developed concurrently to maximize product uniformity, production rate and performance. However, some product lines have been in production for many years, and it is costly to modify them near the end of their life cycle. Therefore, when the idea of producing a tuning robot was introduced, it was decided that RoboCAT should be designed to interface with existing product lines without any modifications, but should be capable of taking advantage of automation friendly enhancements to new products as they are introduced.

A replaceable coaxial screw/nut driver head was created, as shown in ***Figure 4***, allowing simultaneous independent servo driven control of a tuning screw and its lock nut. This capability is crucial in allowing the robot to perform the final tuning screw lockdown on sensitive products where the lockdown procedure can affect the device performance. The system is able to predict the effect of tightening the nut, and make micro adjustments to the tuning screw position to counteract the associated detuning. The screw/nut driver can be easily swapped to handle different screw/nut combinations, and has been used on screws ranging in size from a #2 hex to an M6 Torx. By making the tool heads customizable and interchangeable, the company was able to prove its technology on existing products while ensuring that the machine can take advantage of future product enhancements.

The system is fully compatible with self-locking screws and other nutless screw designs; however, these design elements often have poor passive intermodulation (PIM) performance and are often incompatible with the stringent product specifications of the space and aerospace market. If design specifications allow the use of self-locking screws, the nut driver can be disabled for faster tuning time without changing the tuning procedure.

With the introduction of the automated tuning robot, it was soon discovered that the original CAT tuning strategy was not well suited to machine tuning. There were no checks and balances to allow the algorithm to determine when it had settled on an invalid solution, and tuning runs would sometimes get caught in a loop searching for the best solution. The deficiencies were being masked by the intelligence of manual CAT operators who were unconsciously helping avoid these issues, but became painfully obvious when a machine was blindly following the instructions dictated by the CAT engine.

Working closely with COM DEV technicians on the floor and RF engineers, RoboCAT developers were able to characterize the manual tuning process, and incorporate some of that knowledge into a comprehensive, multifaceted tuning strategy (see ***Figure 5***). New tuning algorithms based on manual techniques were added, and several experimental tuning strategies were made available to the CAT software. An adaptive control algorithm that intelligently selects from the myriad algorithms was employed in an effort to minimize tuning time while maximizing device consistency. The adaptive approach allows the system to tune devices that would be impossible to tune using a single algorithm ap-

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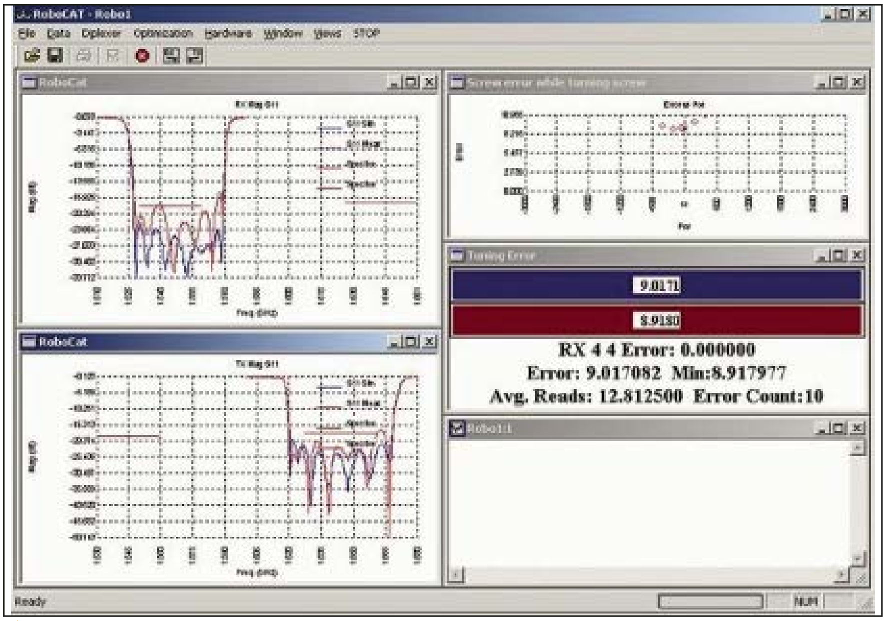
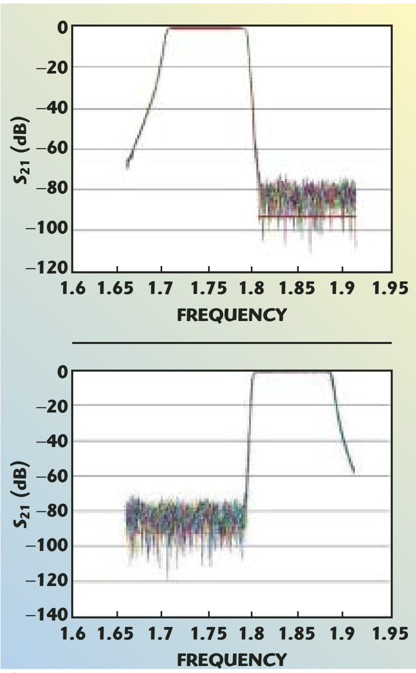


▲ *Fig. 5 An onscreen display shows the status of the current tuning run.*

proach, and increases the allowable physical variation from unit to unit. The resulting CAT methodology combines real-time parameter extraction, sensitivity analysis, automated error vector generation and advanced optimization techniques. The final result is a CAT algorithm suitable for use in a fully automated system that is able to avoid many of the pitfalls of earlier automation attempts.

At each stage in the tuning process, RoboCAT selects from the available tuning strategies based on the results of the previous stage as well as embedded knowledge of the device being tuned. A script-driven decision process controls the actual tuning sequence. Standard generic scripts are used for new products; however, statistical analysis of tuning cycle times can be used to tweak the script to favor the optimal sequence for each product.



▲ *Fig. 6 Overlay of 50 insertion loss measurements for a diplexer tuned using RoboCAT (12-3 and 10-3 filter functions).*

RoboCAT replaces a tedious and unpredictable process with control and repeatability in production. While the adaptive tuning strategy employed by the RoboCAT system is flexible enough to deal with wide device variation, there is a time penalty as additional tuning strategies are engaged to deal with increased deviation from the design "gold standard" unit on which the tuning template was based. By monitoring tuning sequences and times for departures from the norm, production line build issues can be identified for investigation. If tuning times change, a flag is raised indicating that there is a problem upstream in the production line. In this way, the automated tuning station serves as an in-line QA checkpoint. By identifying assembly deviations and bringing build parameters closer to the design template, tuning time is reduced whether robotic or manual tuning is employed. Implementing automation and reducing the human factor from this critical process has increased uniformity and enhanced product quality, as shown in ***Figure 6***.

The RoboCAT system has been found to be faster than an average manual CAT tuner, but the greatest throughput advances are being realized by maximizing machine uptime, minimizing setup and retooling costs, and ensuring that additional parallel machines could be easily added to scale production capacity as needed. Therefore, reliability, consistency, simplicity of use and flexibility were the main design objectives of the RoboCAT team. By operating the machine 20 hours a day, actual throughput per machine easily outpaces several human tuners, and the results are consistently closer to the design template of the device being tuned.

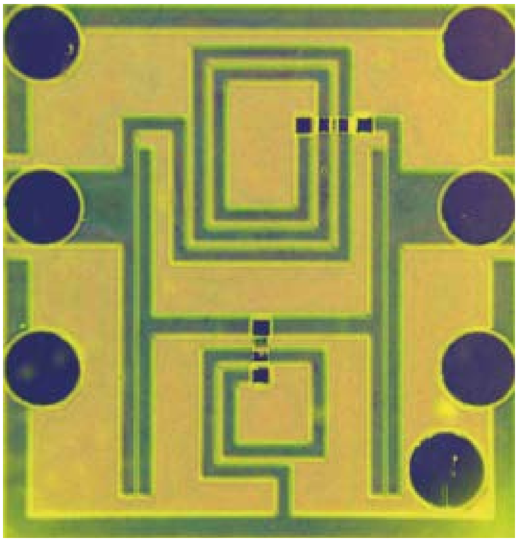
RoboCAT is a highly reliable, low maintenance solution that can be easily scaled as production increases. Because the number of custom hardware components has been minimized, additional machines can be added with very short lead times, thus eliminating tuning capacity as a roadblock to increased production capacity.

Focusing on what they do best, COM DEV relied on internal RF and software expertise to complement a mostly off the shelf mechanical system thus minimizing development time and increasing reliability and flexibility of the whole system. By using off the shelf hardware along with custom software components and proprietary RF analysis tools, the company created a flexible tuning system capable of tuning complex precision filters and multiplexers for aerospace, space and wireless applications. A modularized solution means that the system can be updated with more processing power and faster, more accurate measurement equipment with minimal changes to the system software and hardware. COM DEV has successfully implemented its RoboCAT system for its highest volume products with dramatic improvements in cost, cycle time and product quality. Additional information may be obtained via e-mail at ming.yu@comdev.ca.

COM DEV Ltd.,
Cambridge, Ontario, Canada
(519) 622-2300,
www.comdev.ca/codeone.

RS No. 303

A LOW COST ANALOG PHASE SHIFTER PRODUCT FAMILY FOR MILITARY, COMMERCIAL AND PUBLIC SAFETY APPLICATIONS



A new product family of low cost continuously variable phase shifters (PS) has been introduced. The phase shifters are optimized to reduce size, weight and power consumption (SWAP) as well as unit cost, while increasing switching speed and reliability.

TABLE I

THE FERROELECTRIC PHASE SHIFTER SERIES

Model No.	Frequency Range (GHz)	Application
nPS0712	0.7 to 1.2	Public Safety Radio, Nextel, US Cellular, GSM, 900 MHz ISM, Paging, L-band Radar
nPS1217	1.2 to 1.7	GPS
nPS1726	1.7 to 2.6	PCS, 3G UMTS, 802.11 b/g/n WLAN, WiBro, Bluetooth, Sirius/XM Radio
nPS2538	2.5 to 3.8	MMDS, WiMax
nPS3756	3.7 to 5.6	C-band satellite (Rx), U-NII
nPS4771*	4.7 to 7.1	Public Safety Radio, C-band satellite (Tx)
nPS4060*	4.0 to 6.0	802.11a, Point-to-point

*will be available in Q2 of 2006

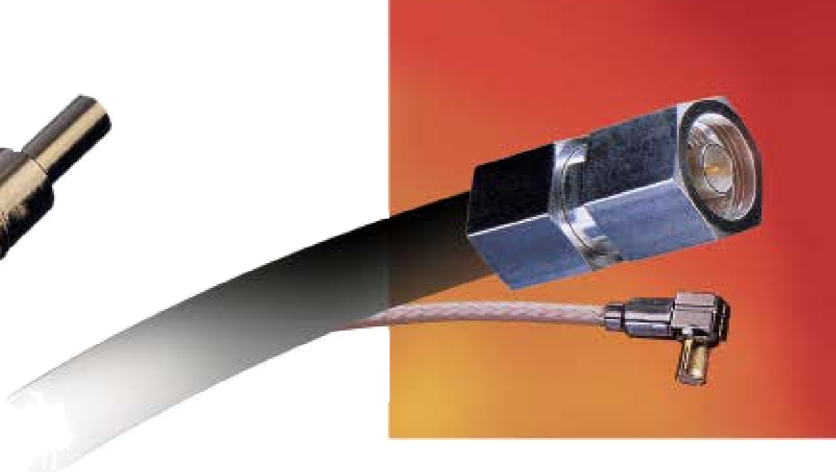
These products are perfectly suited for commercial and military manufacturers to significantly reduce the number of components in the current RF communications systems, and design low cost, high performance solutions for next-generation communications systems that demand new functionalities such as reconfigurable, smart, intelligent devices and systems.

The PS family covers seven frequency bands from 700 MHz to 7 GHz with a minimum phase shift of 90° and a minimum relative bandwidth of 30 percent. The primary applications for these phase shifters include broadband, wireless local area networks (WLAN), base stations, satellite communications, phased-array radar and smart antennas. ***Table 1*** lists the current models with custom models readily available to meet customer's needs.

PRODUCT FEATURES

The phase shifters are manufactured utilizing nGimat's proprietary thin film ferroelectric

NGIMAT CO.
Atlanta, GA



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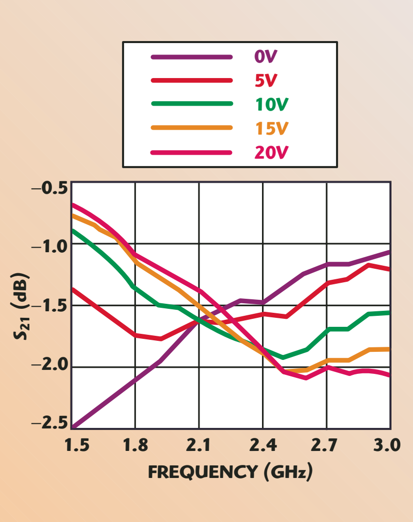
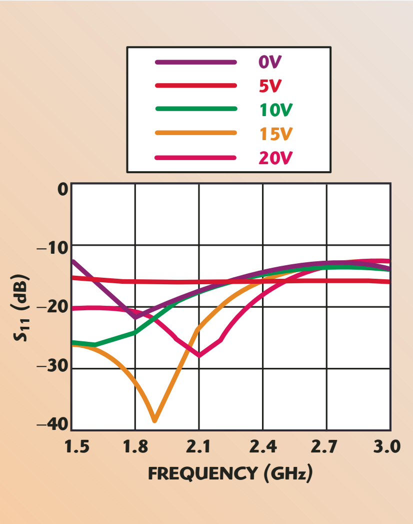
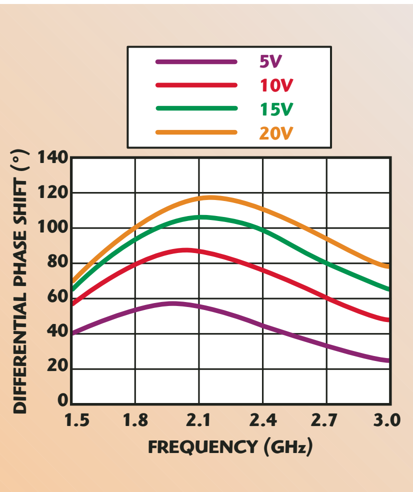


▲ *Fig. 1 Insertion loss of a model nPS1726 S-band phase shifter mounted on a PCB test fixture.*



▲ *Fig. 2 Return loss of a model nPS1726 S-band phase shifter mounted on a PCB test fixture.*



▲ *Fig. 3 Differential phase shift of a model nPS1726 phase shifter.*

barium strontium titanate (BST) on sapphire technology. BST is a high dielectric constant material ($\varepsilon_r > 500$), whose dielectric constant can be tuned down when a DC bias is applied. This makes BST a promising candidate for reconfigurable and tunable devices in numerous RF and microwave applications such as phase shifters, tunable filters and tunable matching networks. nGimat's BST technology is superior to others in the following attributes: (1) the BST thin films are epitaxially grown on inexpensive high Q sapphire substrate using nGimat's proprietary low cost Combustion Chemical Vapor Deposition (CCVD), resulting in higher dielectric constant and tunability, as well as much reduced loss and manufacture cost; (2) a low voltage, planar capacitor structure has been developed by nGimat and the Georgia Institute of Technology, which yields improved intermodulation distortion (IMD) performance. The planar structure also facilitates processing and yields lower loss since thicker and more conductive metals can be deposited than the platinum base electrodes used with BST parallel plate designs.

The phase shifters are fabricated using integrated circuit processing techniques, enabling mass production at low costs. Furthermore, the manufacture of a PS requires fewer processing steps than those of a transistor fabrication, further reducing the fabrication cost when compared to monolithic microwave integrated circuit (MMIC) technology.

The PS is tuned by a single DC bias of +20 or –20 V max, reducing signal routing complexity and allowing precise, continuous phase shift control. Utilizing nGimat's proprietary low voltage capacitor structure, the PS exhibits a high third-order input intercept point (IIP3 > 30 dBm). Lumped element circuits are used for the PS, enabling a compact design and lower loss. A bottom side photo of a flip-chip mountable S-band phase shifter (model nPS1726) is shown next to the article title. The die size is only < 0.080" × < 0.080" × < 0.02". Solder ball terminations and flip-chip packaging are used to reduce device loss and facilitate compatibility to automated industrial manufacturing. The die is fully passivated for high reliability in extreme environments.

Since only passive components are used (compared to conventional PIN diode phase shifters), the phase shifters essentially draw zero static current, enabling long battery life for mobile applications. The drive power required for the BST capacitor is equal to the charge needed to drive the capacitor for one cycle, multiplied by the number of cycles per second, multiplied by the voltage. Assuming a capacitance of 5 pF, a drive voltage of 20 V and an operating frequency of 10 kHz, the BST capacitor requires 10 µW of power. This represents orders of magnitude improvement over the power required to drive a PIN diode.

ELECTRICAL CHARACTERISTICS

Figures 1, ***2*** and ***3*** show the measured S-parameters and differential phase shift of an S-band PS (model nPS1726). It should be noted that the measurement was done with the phase shifter flip chip mounted onto a printed circuit board. A loss improvement of 0.3 dB may be added to account for fixture losses. Therefore, the de-embedded phase shifter, from 1.7 to 2.6 GHz, has an insertion loss of 0.5 to 1.8 dB and a return loss of 14 to 30 dB. Over 100° of differential phase shift is obtained over a 30 percent fractional bandwidth. All the other models exhibit similar electrical performance with the center frequency being the only variable. The typical third-order input intercept point (IIP3) is greater than 30 dBm and can be designed to be 50 dBm, and the switching time of the phase shifter is in the range of tens of nanoseconds. Custom designs can be fabricated to function with 10 V or less control bias and also be integrated to yield up to 360° of phase shift from a single part.

APPLICATIONS

Electronically scanned array antennas offer tremendous benefits over traditional mechanically steered antennas for a variety of radar and communications applications, such as fast, reliable electronic beam steering, compact volume profile, multi-target capability and larger antenna area (gain) for a given system volume. High production costs, however, have hindered the ubiquitous use of these systems. As an essential active component in a phased array, the current MMIC phase shifters account for

SAW Replacement VCOs

FEATURED MODELS

Model #	Frequency (MHz)	Tuning Voltage (VDC)	Typical Phase Noise @10 kHz (dBc/Hz)	Bias Voltage (VDC)	Operating Temperature Range (ºC)
DCSO Series					
DCSO1000-12	1000	0.5 to 5	-128	+12	-40 to 85
DCSO1200-12	1200	0.5 to 12	-125	+12	-40 to 85
DCSO1750-12	1750	0.5 to 12	-120	+12	-40 to 85
DCSO2488-12	2488	0.5 to 12	-117	+12	-40 to 85
DCSR Series					
DCSR100-5	100	0.5 to 5	-130	+5	-40 to 85
DCSR1000-12	1000	0.5 to 12	-120	+12	-40 to 85
DCSR2488-12	2488	0.5 to 12	-115	+12	-40 to 85

Other frequencies are available, please call.

Features:

- Planar Non-Ceramic Resonator
- High Immunity to Phase Hits
- Exceptional Phase Noise
- Very Low Post Thermal Drift
- Small Size Surface Mount
- Lead Free - RoHS Compliant
- Patent Pending
- REL-PRO® Technology

RoHS COMPLIANT

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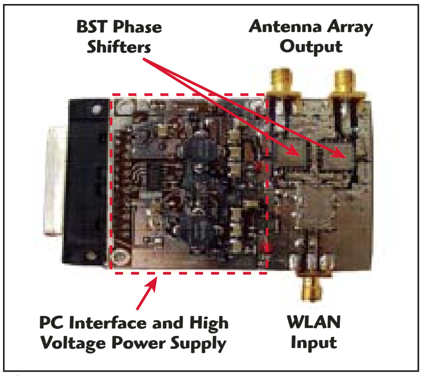
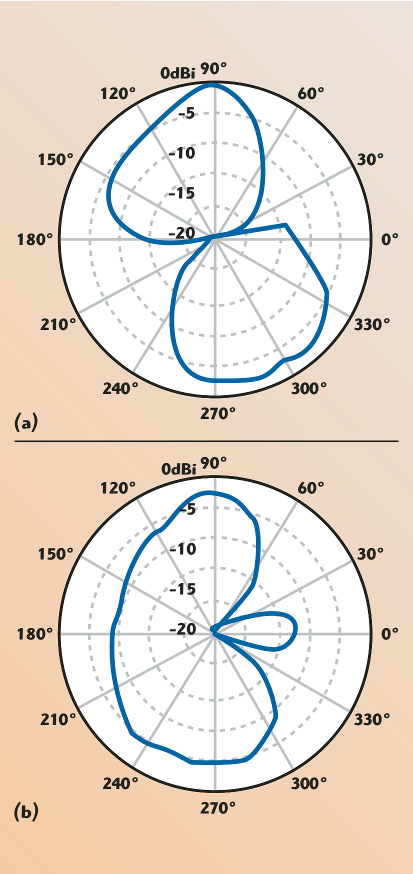
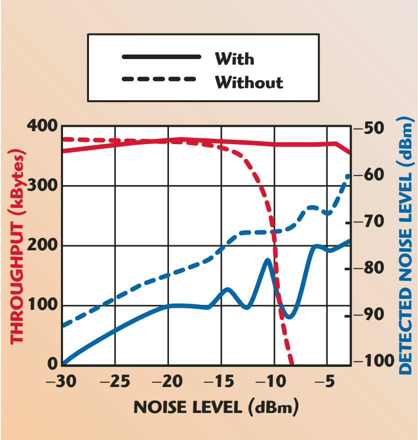


▲ *Fig. 4 A two-element beamforming network realized using BST phase shifters packaged conventionally.*



▲ *Fig. 5 Measured antenna patterns for the two-element array; Δϕ = (a) 0° and (b) 90°.*

nearly 50 percent of the total cost. The introduction of low cost ferroelectric phase shifters will reduce the manufacturing cost of a phased array by at least 50 percent, with additional benefits in SWAP and performance, enabling a broad range of military and civilian applications. Examples of applications include vehicle "on-the-move" antennas, mobile communications, collision avoidance radars, WiFi antennas, conformal antennas and body-born antennas.



▲ *Fig. 6 WLAN performance with and without the BST phased-array antenna.*

Thanks to the explosive growth of WLAN and availability of easy-to-use systems, mobile and wireless communication has become an important part of everyday life. However, the current wireless communications systems have limitations in capacity and performance such as limited spectrum, delayed spread, co-channel interference and multipath fading. Utilizing 2.4 GHz ferroelectric phase shifters, nGimat and the Georgia Institute of Technology have demonstrated a smart antenna system that showed improved data throughput rate and extended range to the access point.

Figure 4 shows a photograph of the two element beamforming network (BFN) fabricated using early prototype phase shifters packaged in conventional leadless chip carrier ceramic packages. Each phase shifter chip consists of a two-section phase shifter, with over 200° of phase shift from 2.4 to 2.45 GHz. The input is connected to an external antenna port on the WLAN card. The BFN is adaptively controlled using the parallel port of the laptop PC connected to the WLAN card. The adaptation is carried out so as to maximize the received bit-error-rate (BER), and hence the data rate of the WLAN. Antenna patterns of the two-element array are measured at 2.4 GHz using an outdoor measurement range. The results are shown in ***Figure 5***. The data show that nulls of more than 20 to 25 dB may be obtained in certain directions, while broad beams are maintained to receive the incoming multipath signals.

A system level field test is performed to ascertain the benefits of the adaptive nulling system as compared to the conventional switched diversity system currently employed on most WLAN devices, as shown in ***Figure 6***. Interference signals at various levels were directed line-of-sight at the laptop computer attached to the WLAN card as it was receiving data from an access point that was not line-of-sight to the phased-array antenna. It is seen that the adaptive nulling afforded by the BST phase shifters achieves a throughput of 350 to 375 kByte/s. This is approximately equal to the throughput of the WLAN card alone until the interference level is increased above –15 dBm (at the source of its transmission). Above this interference level, the throughput rapidly degrades for the conventional switched diversity WLAN antenna, and eventually causes a link failure. In contrast, the adaptive nulling network is able to improve the signal-to-noise ratio sufficiently to maintain full throughput at up to 0 dBm interference level.

The adaptive nulling system described herein could also be applied to anti-jamming systems for global positioning systems, and for co-site interference systems commonly employed in military communications networks. In addition, the BST phase shifters also find applications in RF signal processing, such as adaptive notch filtering and reconfigurable transmitters.

CONCLUSION

A new series of low cost analog phase shifters has been described that covers from L- to C-band with improved SWAP performance. These new phase shifters are perfectly suited for phased-array antennas, smart antennas, and other communications and radar applications.

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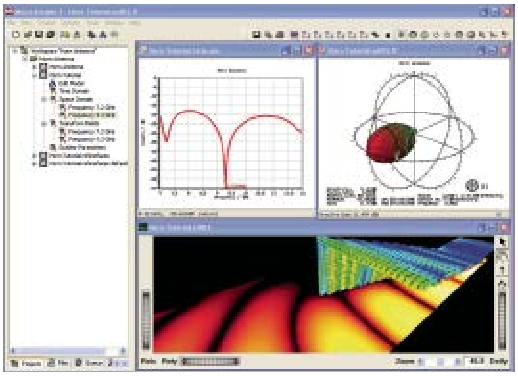
www.ngimat.com.

RS No. 307



An Enhanced Electromagnetic Simulation Tool

When EM engineers use design and modeling packages they want ease of use, reliability and, most importantly, the ability to design new products that meet the desired purpose quickly and effectively. These were the main considerations when Flomerics developed MicroStripes 7, together with the aim of 'bringing electromagnetic simulation to every engineer's desktop.' This aim appears to have been achieved, as the new features of the simulation software have seen productivity gains of up to 60 percent being reported in recent trials by some design engineers.

One aspect of MicroStripes 7 that sets it apart from other commercial electromagnetic simulation software is the core solver technology, which uses a mathematical technique known as the transmission line matrix method (TLM) to solve the time-honored Maxwell's equations. The key advantage of TLM is that it is highly efficient in terms of the amount of computer memory and CPU time required per computational cell, meaning that very large problems can be handled.

Significant new enhancements to Version 7 include 'auto-lumping' of computational cells, an improved user interface, arbitrary plane wave excitation and parametric sweeps to allow optimum designs to be achieved more efficiently. The company has also recently announced an alliance with Applied Wave Research Inc. (AWR) in which the MicroStripes software will provide full 3D analysis capabilities to users of AWR's Microwave Office software.

The development of Version 7 recognizes that the current need for 3D EM simulation is expanding rapidly. Engineers are faced with reduced design cycles, increasing frequencies, demanding performance metrics and, of course, cost considerations. Therefore, they need a tool, which is flexible, easy to use, interoperable with CAD, offers intelligent mesh generation, provides a seamless link with current design tools and is cost effective.

In response to these demands the virtual prototyping environment within the new software allows detailed insight into whether the device or component will meet design criteria even before manufacture. This dramatically reduces de-

FLOMERICS
Hampton Court, Surrey, UK

sign iterations and reduction in design costs, making it a tool that truly addresses the challenges faced by the modern RF/microwave engineer.

AUTO-LUMPING

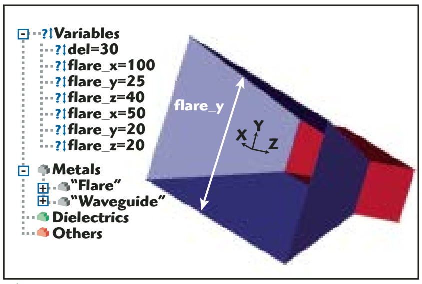
Engineers face an ever-increasing need to solve larger and larger computational problems, which leads to long simulation times and increased computer memory requirements. This is especially so for installed antenna performance, wherein the user models the fine geometric features of a typically small antenna structure in a large and geometrically complex computational volume.

To address this, 'octree' meshing is utilized, which progressively and automatically lumps together computational cells in regions remote from the geometric detail. The ultimate size of the lumped cells is limited only by the local permittivity, permeability and highest frequency of interest. This enables critical but electrically small detail to be captured with an exceedingly high resolution mesh, without having a significant impact on the global cell count.

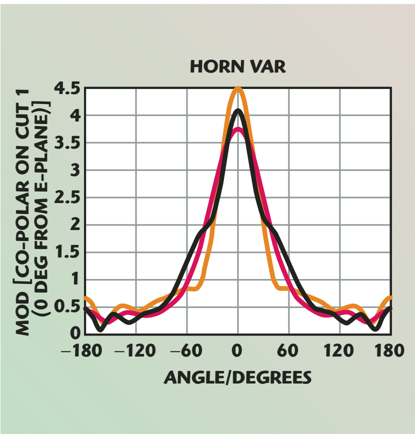
To illustrate the benefit of this feature consider an aircraft measuring 26 m by 26 m by 8 m, which has been imported as a hollow metal object into Version 7. The aircraft is surrounded with free space of 10 m in each direction, giving a total computation volume of about 59,248 m3. The aircraft is illuminated by an off-axis plane wave with maximum frequency of 100 MHz. ***Figure 1*** shows the surface current distribution graph.

What is noticeable is that a very fine mesh is applied to capture the detail of the structure. However, due to the automatic lumping, the total cell count is only about 3.6 million, which is a 99.3 percent savings compared to the graded mesh of 529 million cells before lumping. The lumping is mainly performed inside the aircraft and in the

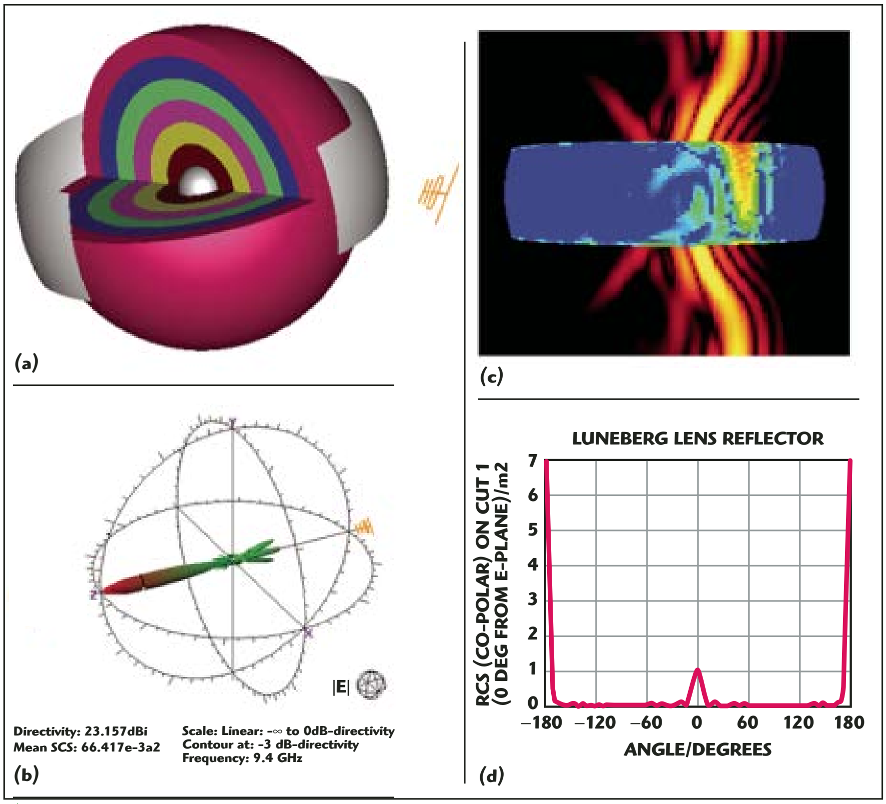
▲ *Fig. 1 Surface current distribution on an aircraft.*



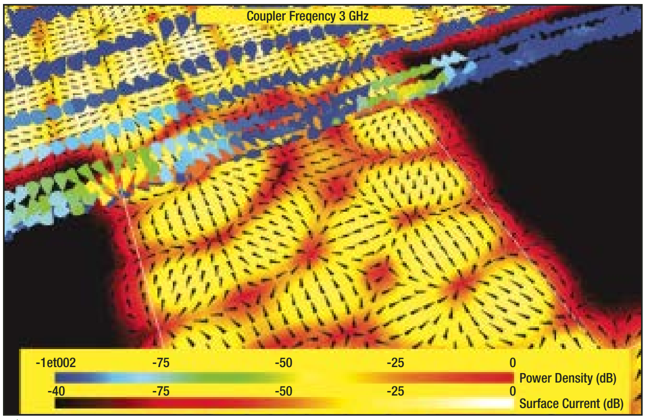
▲ *Fig. 2 A horn antenna model with variable definition.*



▲ *Fig. 3 Horn directivity varied with different values of flare_y.*



▲ *Fig. 4 A Luneberg lens reflector illuminated by 45° polarized plane wave (a), and the corresponding simulated results: (b) 3D far-field plot, (c) the current and E-field distribution at 5.7 ns and (d) the RCS co-polar cut at 9.4 GHz.*



▲ *Fig. 5 Current flow distribution on a 3 dB coupler.*

free space, while keeping a fine mesh on the metal surface of the aircraft. Significantly, the simulation was completed within 17 hours on a dual 1.99 GHz AMD Opteron and the memory usage was only 609 Mbytes.

PARAMETRIC SWEEP

In RF design work, engineers often need to modify features of a design to tune for the best performance. MicroStripes 7 facilitates such tuning by allowing variables and mathematical operators in geometric parameters. The simulation can then sweep a variable in regular steps, between the minimum and maximum set values defined.

As an example of this feature, the horn antenna shown in ***Figure 2*** has variables defining the dimension of the objects in the model. Flare_y is the horn opening in the direction of the Y-axis, which has been given a set of values, swept from 25 mm to 75 mm in two steps. Version 7 automatically applies the variable sweep as part of the simulation. The results for different variable values can then be compared in a single graph. ***Figure 3*** shows the change in the directivity due to different values of flare_y. The red, black and purple traces represent the antenna directivity when flare_y is equal to 25, 50 and 75 mm, respectively.

RADAR CROSS-SECTION PLANE WAVES

The extension of the plane wave excitation to allow arbitrary angles of incidence means the mono-static and bi-static radar cross-section (RCS) can quickly and easily be determined. Plane wave incidence from any angle is allowed, with any transverse polarization. RCS results can then be visualized in a 3D far-field plot and in 2D far-field cut planes.

As an illustration, consider the Luneburg lens radar-reflector, shown in ***Figure 4***, which is commonly carried by yachts in order to increase their visibility to larger vessels. This dielectric device is spherical and has a permittivity that varies along the radius. Plane waves incident from any direction are focused to a point on the far surface. To make a retro-reflector, the lens surface in the region of the focus is metalized. Radiation reflected at the focus is collimated in passing back through the lens, and sent back to its original source. In order to show the metal band, the outmost layer of dielectric is hidden. The figure also shows the scattered field for the lens reflector illuminated by a 45° polarized signal. A little yellow Yagi antenna is used to symbolize the propagation direction and polarization of the incident plane wave.

The 3D far-field plot generated by EM simulation software shows a value for the mean scattering cross-section (SCS). If the mouse is moved over the plot, then the varying value for the RCS is reported in the window footer. This value of RCS relates to direction under the mouse and for the plotted polarization, that is, both the directive gain and polarization loss are factored in. Alternatively, the RCS result can be seen in the cuts plots; for example, a co-polar far-field cut is provided in ***Figure 4***.

SOFTWARE PARTNERSHIP

Also significant in the development of Microstripes 7 is the partnership that Flomerics has entered into with AWR in order to provide users with an enhanced data transfer using the AWR EM Socket interface. This will enable Microwave Office users to transfer data to the MicroStripes 3D solver, allowing comprehensive analysis of antennas, filters, couplers, interconnects, planar structures and packaging effects. The open architecture format makes this straightforward, yet yields great benefits in terms of re-using data and speeding up the overall RF design flow. A typical example is illustrated in ***Figure 5***, which shows the current flow distribution on a 3 dB coupler.

CONCLUSION

MicroStripes 7 represents a significant forward leap in electromagnetic modeling software and reinforces the company's position as a leading provider of 3D electromagnetic virtual-prototyping software. The most significant improvements are an enhanced user interface; automatic octree meshing; intuitive parametric sweeps; and arbitrary plane wave illumination for radar cross-section applications. The alliance between AWR and Flomerics will also significantly improve the design flow between 2.5D and 3D RF/microwave design.

Flomerics, Hampton Court, Surrey, UK + 44 20 8487 3000, info@flomerics.co.uk, www.flomerics.com.

RS No. 300


contact
Microwave and Millimeterwave
Products and Solutions...
18 to 140 GHz.
WiseWave Technologies, Inc. designs, develops and manufactures eight full categories of standard and custom microwave and millimeterwave products, including amplifiers, antennas, control devices, ferrite devices, frequency converters, oscillators, passive components and integrated assemblies up to 140 GHz.
Contact us.
VISA
MasterCard
WiseWave
Technologies, Inc.
3043 Kashiwa Street, Torrance, CA 90505
Tel (310)-539-8882, Fax (310)-539-8862
www.wisewave-inc.com
sales@wisewave-inc.com

Prototype Quantities On-line

ATC QUIKBuy™ provides a site where customers may place on-line orders for small product quantities. ATC QUIKBuy offers the EIA-size ultra-low ESR capacitors, the 600F (0805) and 600S (0603). ATC has now expanded its on-line product offerings to include the 600L (0402), as well as RF capacitors, the 100A (0505) and 100B (1111). The product selector enables customers to easily select specific capacitance values and case sizes. ATC QUIKBuy also creates an on-line customer profile to expedite repeat orders.

American Technical Ceramics,
One Norden Lane,
Huntington Station, NY 11746

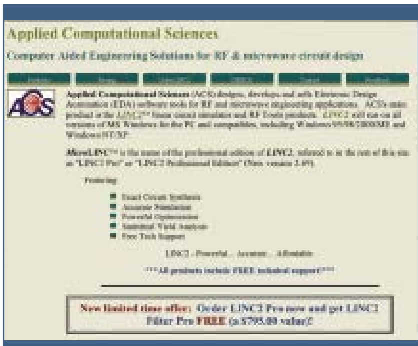
www.atceramics.com

RF and Microwave Filters

This web site introduces a new line of ceramic bandpass, cavity diplexer and monoblock ceramic bandpass filters for WiMAX applications. In addition, standard and custom RF and microwave filters for military, commercial and wireless applications are listed. Products include bandpass, low pass, high pass, bandstop and voltage-tuned filters, as well as diplexers, multiplexers and switched filter banks. The site also includes ordering information and convenient on-line quote and catalog requests.

Anatech Electronics Inc.,
70 Outwater Lane, Garfield, NJ 07026

www.anatechelectronics.com



RF and Microwave Circuit Design Software

The company's web site has been updated to highlight new features of the LINC2 RF and microwave circuit design software. LINC2 combines high performance RF and microwave circuit design, synthesis, simulation and optimization into a single integrated program at an affordable cost. The software includes a suite of design tools for the exact synthesis of a wide variety of active and passive circuits.

Applied Computational Sciences,
1061 Dragt Place, Escondido, CA 92029

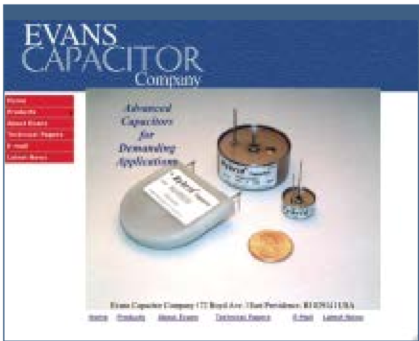
www.appliedmicrowave.com

On-line Ordering

Ordering from the company has become easier with the addition of on-line ordering. Registered users are able to select products, enter billing and payment information, and receive acknowledgment of the order. The web site also features detailed product pages with downloadable specification sheets, software demos and application notes. The web site includes a search that allows users to search by amplifier, keyword, power and/or frequency.

AR Worldwide RF/Microwave Instrumentation,
160 School House Road,
Souderton, PA 18964

www.ar-worldwide.com



Energy Dense Capacitors

This web site highlights the company's energy dense capacitors. These hermetic, tantalum Hybrid® capacitors claim to be four times more energy dense than other tantalum wet capacitors and are used in phased-array radars, laser targeting, microwave communications modules, controls, displays, fire control systems on F-35 JSF and other aircraft. The site offers more than two-dozen tutorials, white papers and abstracts pertaining to supercapacitors.

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

www.evanscap.com

On-line Quality Center

The Quality Center is a comprehensive on-line resource center of the company's quality systems that is accessible 24/7. Visitors can create a custom quality report, take a video tour of its 230,000 sq. ft. factory, or walk through every step of the quality process. Visitors can browse the company's entire Quality Process including reliability calculator, traceability and customer satisfaction procedures; and view the Quality library including Quality brochure, data sheets and white papers.

Vicor Corp.,
25 Frontage Road,
Andover, MA 01810-5413

www.vicorpower.com

● On-line Web Store

This on-line web store allows engineers to easily and quickly order flexible microwave test cable assemblies. With the web store, the company offers a cost-effective alternative that helps engineers who need high frequency cable assemblies for defense, telecommunications and test instrument designs. The site features a completely integrated design tool that details features and benefits of all products, enabling the user to select optimum cable, connector and armor combinations.

Micro-Coax,
206 Jones Boulevard,
Pottstown, PA 19464-3465

www.microcoax.com

● Time and Frequency Products

This web site serves customers faster and more efficiently by using a key word to access a search engine for specific products, data sheets and references. It focuses on the company's time and frequency core business, and is geared to offering customers innovative solutions while enhancing design, customer service, flexibility, quality and technology expertise. The site also offers the facility for directly downloading application notes, which can be found in the support and documentation section.

Temex SAS,
399, route des Crêtes – BP 232, 06904
Sophia-Antipolis, France

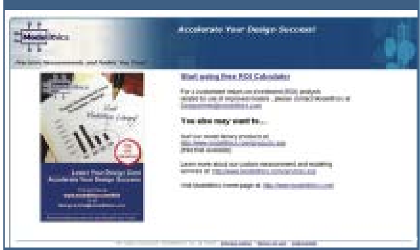
www.temex.com

● The Home Page of the Microwave Industry

Completely redesigned and featuring a new look and new features, this web site is the RF/microwave professionals' portal to the latest news, industry events, market data, new product information, technical articles, suppliers and resources. The new Buyer's Guide allows users to navigate through sharply defined categories in their search for products from more than 1000 manufacturers. Unique resources on the site include the RF to Light 100 stock index and the Custom Cable Assembler.

Microwave Journal,
685 Canton Street, Norwood, MA 02062

www.mwjournal.com



● Free ROI Calculator

This new web site features the company's high precision measurements and models for microwave/RF design simulation. The site includes a free return-on-investment (ROI) calculator for design and simulation improvement projects. See how better models for a design will bring about a significant cost savings. Whether you develop models yourself or purchase Modelithics' custom or standardized models, your budget will benefit.

Modelithics Inc.,
3650 Spectrum Boulevard, Suite 170,
Tampa, FL 33612

www.modelithics.com/roi

● Noise Components and Test Equipment

This web site features the company's reliable noise sources and test equipment. It provides users detailed information on these products in an easy to navigate format. The structure and format of the site enables customers to quickly find technical specifications on all the company's instruments and noise sources. Detailed product data sheets, the company's latest press releases and a variety of quick tips are also provided within the site.

NoiseWave Corp.,
11 Melanie Lane,
East Hanover, NJ 07936

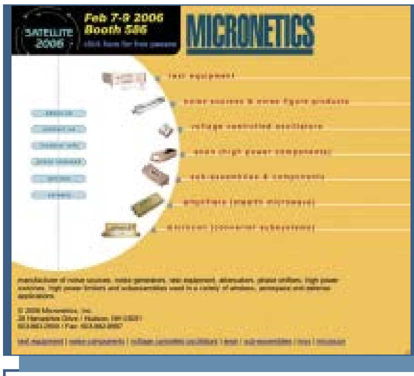
www.noisewave.com

● High Frequency Electromagnetic Simulation Software

This redesigned web site features easier navigation and updated product information. The site focuses on its products and the applications. "Tips of the Week" is an integral part of the site that features some of the most useful tips that have proven indispensable by the users of the company. The site continues to provide SONNET Lite, a full-featured electromagnetic field simulation for free.

Sonnet Software Inc.,
100 Elwood Davis Road,
North Syracuse, NY 13212

www.sonnetsoftware.com



Components, Subassemblies and Modules

This web site converges technology, intellect and skills to design and manufacture comprehensive solutions in the form of microwave components, integrated subassemblies and multi-function RF modules. The company operates seven product development groups, consisting of receiver components, high power components, switch filters, converter subsystems, VCOs, amplifier products and noise product groups.

Micronetics Inc.,
26 Hampshire Drive, Hudson, NH 03051

www.micronetics.com

ICs, Modules and Subsystems

This comprehensive, versatile web site details full specifications for over 390 products, RoHS compliance, application notes, quality assurance and product software support tools including Product Cross Reference, Parametric Search, PLL Phase Noise and Mixer Spur Chart Calculators, and expanded E-commerce. The 2005 Autumn Product Selection Guide, Newsletter and CD are currently available and can be requested from the company's site.

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

www.hittite.com

Low Noise Frequency Components and Systems

The web site details the company's product line that consists of low phase noise crystal oscillators, synthesizers and frequency related modules. The site has been recently updated to include easy access to data sheets and custom capabilities. A technical library is also accessible via the site.

Wenzel Associates Inc.,
2215 Kramer Lane, Austin, TX 78758

www.wenzel.com

NEW WAVES: Test, Measurement and CAD

Digital Vector Signal Analysis

This combination of solutions tightly integrates the digital signal capture power of the company's logic analyzers with its 89600 series vector signal analysis (VSA) software. The result is a powerful digital vector signal analysis measurement system that delivers precise, accurate modulation measurements on the digitized communication signals found in DSP-based radio transceivers. Digitized transmit and receive signals found on data buses between the baseband and RF blocks of digital radio applications can be analyzed in the time, frequency and modulation domains within a logic analyzer just as if they were in full analog form.

Agilent Technologies Netherlands B.V.,
Amstelveen, The Netherlands
+31 20 547 2000, www.agilent.com.

RS No. 216

Bluetooth EDR Test Set

The MT8852B Bluetooth test set is designed for high speed testing of Bluetooth Enhanced Data Rate (EDR) products. It performs the new radio layer measurements defined in the Bluetooth Revision 2.0 EDR standard, along with the basic rate measurements, from a single "RUN" button key-press. To ensure reliable connections with other Bluetooth products, the MT8852B performs transmitter error vector magnitude and receiver sensitivity tests at the higher data rates. The test set also offers a typical test time of less than 10 seconds for new EDR products, meeting the demands of high volume manufacturing lines. Price: $24,000.

Anritsu Co.,
Richardson, TX (972) 644-1777,
www.anritsu.com.

RS No. 217

Surface-mount Noise Source

The model NW2G-B-SM is a surface-mount packaged noise source ideal for surface-mount PCB applications. Offering broadband frequency coverage from 200 kHz to 2 GHz, the NW2G-B-SM features at least 31 dB ENR with flatness of ±1.5 dB or better. All bias circuitry is included so standard operation is from +15 VDC with a 10 mA maximum current draw. Applications include built-in test equipment, dithering for increased dynamic range of A/D converters, jamming and as an economical source for broadband power.

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

RS No. 221

Broadband Amplifiers

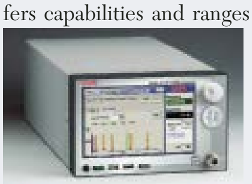
The model 15S5G7 (15 W) and model 30S5G7 (30 W) amplifiers operate in the 5 to 7 GHz frequency range. These broadband amplifiers are well suited for testing WiMAX components because of the amplified signal the models produce is virtually indistinguishable from the signal generator's output. Since the linearity of the amplifier signal is as strong as the signal generator there is no interference with adjacent channels. In addition, the units' high peak-to-peak power ratio means the amplifiers deliver more useable power.

AR Worldwide RF/Microwave Instrumentation,
Souderton, PA (215) 723-8181,
www.ar-worldwide.com.

RS No. 218

RF Vector Signal Generator

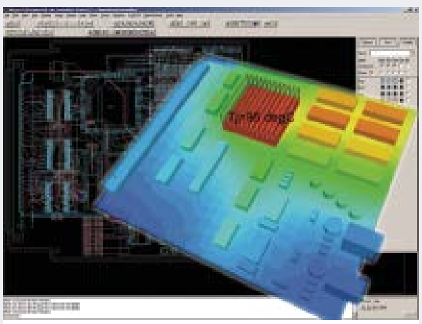
The model 2910 RF vector signal generator offers capabilities and ranges that make it ideal for production testing of today's mobile handsets as well as for applications such as communications research, the testing of mobile communications infrastructure, RFICs and wireless connectivity devices. This model is designed to execute key tasks such as frequency tuning, amplitude switching and waveform changes that increase throughput and lower test costs. This generator's continuous frequency range of 400 MHz to 2.5 GHz spans key mobile wireless bands. Digital waveforms are built-in for key handset testing in the major cellular formats. This system also supports various forms of analog modulation and noise tests.



Keithley Instruments Inc.,
Cleveland, OH (440) 248-0400,
www.keithley.com.

RS No. 220

Thermal Design Software



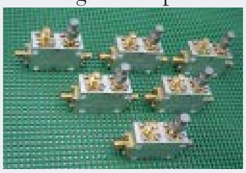
Version 3.0 of the FLO/PCB thermal design software, FLO/PCB for Allegro provides a link to Cadence® Allegro® PCB Editor software that allows designers to simply call up a menu item on the Cadence software and, with a few mouse clicks, generate a thermal model of their design. The FLO/PCB/Allegro interface transfers information about the PCB's geometry and components needed to perform thermal analysis. This includes the number of metallic layers, the type of each layer such as signal or power or ground plane, the coverage of copper on the board, and the location and power dissipation of each component. The interface also allows the user to select the appropriate layer used to derive the physical extents of the package.

Flomerics Ltd.,
Hampton Court, UK +44 (0) 20 8487 3000,
www.flomerics.com.

RS No. 219

Directional Coupler

These application specific directional couplers are designed for power sampling and VSWR monitoring in WiMAX applications. The couplers operate at 2.5 and 3.5 GHz and are available in coupling values of 10, 20 and 30 dB nominal. Electrical performance offers typical insertion loss of 0.5 dB, isolation of 18 dB minimum, VSWR of 1.25 typical and directivity of 15 dB maximum. Forward power handling is 50 W CW. Size: 1.38" × 0.95" × 0.59", plus connectors.



Response Microwave Inc.,
Framingham, MA (978) 456-9184,
www.responsemicrowave.com.

RS No. 222

EDR with Loopback Test Mode

Bluetooth V2.0 + Enhanced Data Rate (EDR) options are available for the R&S CBT and R&S CBT32 RF testers. Fitted with the EDR option, the testers allow all measurements – with the exception of EDR C/I performance – to be performed without any external equipment or PCs. With regard to EDR receiver tests, the option supports the loopback test mode in accordance with the specification. The loopback test mode verifies the receiver sensitivity of an existing Bluetooth link under virtually realistic conditions. Like the basic versions, the R&S CBT and the R&S CBT32 with EDR option feature high measurement speed. Lab tasks can thus be handled more quickly, reducing test times and costs in production.

Rohde & Schwarz GmbH & Co. KG,
Munich, Germany +49 89 4129-13779,
www.rohde-schwarz.com.

RS No. 223

COMPONENTS

PIN Diode Switch

The model MSN-2DT-05-IND with option 561R310H01 is an absorptive, SPDT PIN diode switch that operates from 50 to 500 MHz. This hermetically sealed switch offers a typical insertion loss of less than 1 dB, a typical isolation of 65 dB and a typical VSWR of 1.25. The switching speed is <200 ns while the peak RF input is +30 dBm. Input signals of +10 dBm will result in an output harmonic of –70 dBm maximum. The DC power supply is +5 VDC at 100 mA maximum. Size: 1" × 1" × 0.4".

American Microwave Corp.,
Frederick, MD (301) 662-4700,
www.americanmicrowavecorp.com.

RS No. 224

PIN Diode Attenuator

The model A0P-69N-0AB is a 2 to 18 GHz PIN diode attenuator that is capable of a 105 dB dynamic range in monotonic 0.03 dB steps. Attenuation flatness is ±1 dB to ±8 percent of set value. VSWR is less than 2.2 and the insertion loss is 5 dB. The attenuator is digitally controlled via 12 bits of TTL compatible binary logic with a switching speed less than 350 ns. Size: 2" × 3" × 0.75".

G.T. Microwave Inc.,
Randolph, NJ (973) 361-5700,
www.gtmicrowave.com.

RS No. 226

Power Splitters/Dividers

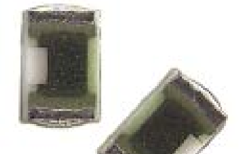
The In-Line two-, three- and four-way power splitters/dividers are now available with SMA connectors. These Wilkinson style power dividers, Dx-64FF series, cover the frequency range from 800 to 2500 MHz to include the cellular, PCS and UMTS bands in a single unit. Each divider has been designed for low power applications where output isolation is preferable over lowest possible loss. The wide frequency range of this design allows use with multiband antennas and leaky cable systems.

Microlab/FXR,
Parsippany, NJ (973) 386-9696,
www.microlab.fxr.com.

RS No. 231

Surface-mount Chip Resistors

The Super RCX series of thick film wrap-around surface-mount chip resistors offers twice the power handling in the same footprint for users who need more power, but do not want the higher cost of BeO Beryllia and AlN aluminum nitride. Super RCX resistors eliminate the need for redesign to accommodate higher power. The same resistor size and footprint is able to be maintained. Resistor sizes available include 0402, 0603, 0805, 1206 and 2512. Ohmic values of resistance range from 10 ohm to 1 megohm. Termination metals are PtAg platinum silver and platinum silver with a 62/36/2 solder coating.



International Manufacturing Services Inc.,
Portsmouth, RI (401) 683-9700,
www.ims-resistors.com.

RS No. 228

Eight-channel Switch Bank

The model 8IFA-1340/2440-SR is an eight-channel switch bank that covers the frequency range from 1340 to 2440 MHz. The bank utilizes MMIC switch technology for minimum size and maximum electrical performance. Supply voltage is specified as +5 V at 10 mA. Attenuation points are specified as 35 and 65 dB with a VSWR of 2.0 standard. The unit features a 4.8 × 3.3 × 0.50 package with SMA female connectors.

Lorch Microwave,
Salisbury, MD (410) 860-5100,
www.lorch.com.

RS No. 229

5 W Coaxial Attenuators

These 5 W, type N and SMA male-to-female coaxial attenuators are ideally suited for demanding power applications that operate from DC to 6 GHz. Standard attenuation values of 3, 6, 10, 20 and 30 dB are available from stock. These attenuators feature good accuracy of 0.3 dB and low VSWR of 1.15 while handling 5 W of continuous power at 500 W peak. Delivery: available from stock.

MECA Electronics,
Denville, NJ (973) 625-0661,
www.e-meca.com.

RS No. 230

Power Dividers/Combiners

These high performance power dividers/combiners are primarily used to distribute or combine RF power from signal sources. Components like the eight-way model shown operate in a frequency range from 3 kHz to 26.5 GHz and offer high isolation, low insertion loss, as well as standard SMA or N connectors. Many items are in stock and available for immediate delivery.

Microwave Communications Laboratories Inc.,
Saint Petersburg, FL (727) 344-6254,
www.mcli.com.

RS No. 232

Digital Phase Invariant Attenuator

The model DPAT-135145-32-08-0.125 is a digital phase invariant attenuator that covers the frequency range from 13.5 to 14.5 GHz. As the attenuation is varied over its entire 32 dB range the phase shift remains within a maximum of 7°. The insertion loss is less than 2.5 dB and attenuation is performed in steps of 0.125 dB. The attenuator is controlled by an 8-bit digital word with an accuracy of 1 dB. Options available include attenuation ranges to 60 dB and other frequency bands.

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

RS No. 233

Band Reject Filter

The model 5MBR17R1G-40DB-CD-SFF is a band reject filter that offers a low passband insertion loss of 1 dB maximum from 2 to 16.7 GHz while providing over 40 dBc of band rejection at 17.1 GHz. This filter is used mainly to reject unwanted frequencies that are close to the desired passband and when a low pass filter is not steep enough. The filter is temperature stable and maintains all of the specifications over the –55° to +85°C temperature range. Many other frequency ranges and notch depths are available over the 500 MHz to 26.5 GHz range.

Planar Filter Co.,
Frederick, MD (301) 662-5019,
www.planarfilter.com.

RS No. 235

High Power 180° Hybrid

The model JTP-10-450/1 is a three-port, 180 degree hybrid released for the 10 to 100 MHz frequency range with input power handling of 50 W. Specifications include insertion loss of 0.6 dB, VSWR of 1.4, isolation of 20 dB and phase balance of 180 ±3 degrees. Size: 2.1" × 2.1" × 1". The unit is available with either SMA or type N connectors.

Pulsar Microwave Corp.,
Clifton, NJ (800) 752-2790,
www.pulsarmicrowave.com.

RS No. 237

High Power Narrowband Notch Filter

The model 5R7-1.775-20S11 is a narrowband notch filter with the notch center at 1775 MHz. The notch depth measures 60 dB with passbands from DC to 1757 MHz and 1793 to 5000 MHz. Insertion loss measures 1.5 dB in the passband, and passband VSWR is less than 1.5. This unit can withstand 15 W CW of power although other power levels are available.

Reactel Inc., Gaithersburg, MD (301) 519-3660, www.reactel.com.
RS No. 238

Drop-in Isolator

The L-series of flange-mount drop-in isolators features up to 15 percent bandwidth in the 8 to 40 GHz frequency range. This series is ideal for military and space applications and is made of a steel housing that is gold plated for better RF performance. This temperature stable device offers a typical loss of <0.4 dB and VSWR and isolation >20 dB. Size: 0.25" × 0.50" × 0.18".

Renaissance Electronics Corp., Harvard, MA (978) 772-7774, www.rec-usa.com.
RS No. 239

Low Pass Coaxial Bandpass Filters

These sixteen bidirectional tubular bandpass filters operate in a frequency range from 2 to 18 GHz. The rugged designs provide low Tchebycheff ripple of 0.01 dB in passband and offer 55 dB rejection in the stopband. Standard connector interfaces are SMA and type N, but other connector series are available.

Filtronic Signal Solutions Inc., Hudson, NH (603) 459-1600, www.filss.com.
RS No. 240

AMPLIFIERS

High Power Amplifier

The model SSPA 2.2-2.3-20-ODU is a high power amplifier that is employed in an outdoor unit configuration and is mounted on an antenna hub. This specialty power amplifier is employed as a satellite ground station uplink transmit amplifier for the TDRSS family of spacecraft. This amplifier consists of an AC/DC converter, multiple amplifier assemblies, output filtering and an environmentally sealed housing including lighting protection. This module operates from 2.2 to 2.3 GHz and delivers a minimum of 20 W of RF power to the antenna. Size: 9.09" × 11.80" × 3.03".

Aethercomm Inc., San Marcos, CA (760) 598-4340, www.aethercomm.com.
RS No. 242

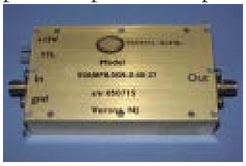
2 to 18 GHz Switched Bypass Amplifier

The model AML218PS3601 is a 2 to 18 GHz switched bypass amplifier with a high gain state of 36 dB and a low gain state of 0 dB. Flatness over frequency, in either mode, is +1.5 dB. Noise figure in the high gain state is 8 dB with a P1dB output power of +22 dBm. Input and output VSWR is 2.0. Gain state selection is by TTL compatible interface. Model AML218PS3601 is part of a series that offers several gain and switch configurations. DC operating voltage is 11 to 18 VDC at 850 mA. Size: 1.7" × 1.4".

AML Communications Inc., Camarillo, CA (805) 388-1345, www.amlj.com.
RS No. 243

High Power Amplifier

The model 50AMP8.5G9.5-40-37 is a high power amplifier that operates in the frequency



range from 8.5 to 9.5 GHz and is ideal for wireless, defense and satellite communications. The output power at 1 dB compression is at least 37 dBm and gain is 40 dB. Noise figure is 7 dB, input voltage is +12 V and current draw is less than 3.5A. The unit is supplied with TTL control, which turns current off to the unit. Additionally, the unit is equipped with an integral isolator at the output. Size: 3" × 5" × 1".

Amplical Corp.,
Verona, NJ (201) 919-2088,
www.amplical.com.

RS No. 244

Low Noise Amplifiers

The model HMC376LP3E and the model HMC382LP3E are GaAs PHEMT MMIC low

noise amplifiers (LNA) that operate from 700 to 1000 MHz and 1700 to 2200 MHz, respectively. These LNAs require little or no external matching, and are footprint/pinout compatible such that a single PC board design can be used to implement either part number. With noise figures as low as 0.6 dB, and up to +36 dBm of output IP3, the HMC376LP3E and the HMC382LP3E MMIC LNAs are ideal for front-end receivers, and repeaters in GSM/GPRS, CDMA, WCDMA and TD-SCDMA applications.

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

RS No. 246

Low Noise Amplifiers

Models XL1003, XL1004 and XL1005 are gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) low noise amplifiers (LNA). Using 0.15 micron gate length GaAs pseudomorphic high electron mobility transistor (PHEMT) device model technology, the devices operate in a frequency band from 5 to 45 GHz and offer low noise performance achieving 1.7 dB. These LNAs are well suited for millimeter-wave point-to-point radio, LMDS and SATCOM applications.

Mimix Broadband Inc.,
Houston, TX (281) 988-4600,
www.mimixbroadband.com.

RS No. 248

MMIC Amplifiers

This family of "Lee" MMIC amplifiers is highly reliable, extremely broadband and low in cost.

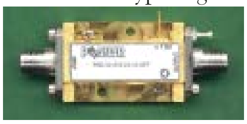
These amplifiers offer good electrical performance, with up to 17.3 dBm flat output power to 10 GHz. These five models are housed in a leadless 3×3 mm low profile (MCLP™) package with exposed metal bottom for good grounding and heat dissipation. This series offers high reliability and repeatability. These amplifiers are ideal for the cellular, PCS, communication receivers and transmitters as well as for satellite communication and military applications. Price: from $1.19 ea. (25).

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

RS No. 249

Amplifier

The model PM2-32-818-23-12-SFF amplifier offers 32 dB typical gain from 8 to 18 GHz.



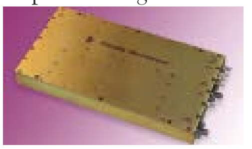
The gain flatness is better than ±2 dB, noise figure is <4 dB and the OP1dB is >23 dBm. This model offers in/out VSWR of 2.0 maximum and current of 800 mA at +12 VDC maximum. The amplifier is packaged in the standard PM2 housing with other housings available.

Planar Electronics Technology,
Frederick, MD (301) 662-5019,
www.planarelectronicstechnology.com.

RS No. 250

Ultra-linear RF Amplifier

The model SM4450-43L is a 20 W GaAs FET amplifier designed for various military and



commercial applications demanding high performance. The unit operates from 4.4 to 5 GHz with a

P1dB of +43 dBm and OIP3 of +62 dBm. Small-signal gain is 55 dB with a flatness of ±0.5 dB across the band. Standard features include a single +12 VDC supply, thermal protection with auto reset and over/reverse voltage protection. Size: 7.5" × 3.97" × 0.79".
Stealth Microwave Inc.,
Trenton, NJ (609) 538-8586,
www.stealthmicrowave.com.

RS No. 251

Variable Gain Amplifier

The model VG025 is a high dynamic range variable gain amplifier that is capable of

achieving an analog attenuation range of up to 21 dB. The +21 dBm output compression point and +40 dBm output intercept point of the amplifier are maintained over the entire attenuation range while operating over the 50 to 2200 MHz range making it ideal for either IF or RF applications. This model is packaged in a 16-pin 4×4 QFN package that is lead-free/green/RoHS compliant.
WJ Communications Inc.,
San Jose, CA (408) 577-6200,
www.wj.com.

RS No. 253

DEVICE

High Power Transistors

Models 1517-20M, 1517-110M and 1517-250M are high power transistors that target high L-band pulsed radar

applications from 1480 to 1650 MHz with a pulsed output power of 20, 110 and 250 W, respectively. These transistors are designed to handle medium pulse widths of 200 µs with a duty cycle of 10 percent. The high performance, common base, class C, output stage, for example, offers 250 W of peak power, 40 percent collector efficiency and low droop, 0.5 dB or less across the 200 µs pulse width.
Advanced Power Technology,
Bend, OR (541) 382-8028,
www.advancedpower.com.

RS No. 254

INTEGRATED CIRCUITS

Handset Module Solution

The POLARIS 2™ TOTAL RADIO™ module solution is comprised of a cellular transceiver module and a cellular transmit module for handsets operating on the GSM/GPRS and GSM/GPRS/EDGE networks. The performance, size and cost advantages of this solution enable handset manufacturers to quickly and cost-effectively introduce smaller, more feature-rich handsets capable of delivering the advanced levels of functionality and services of today's high data-rate networks. This new solution is a complete, two-placement radio consisting of transceiver and transmit modules designed to support up to four frequency bands while operating under the GSM, GPRS and EDGE air interface standards.
RF Micro Devices Inc.,
Greensboro, NC (336) 664-1233,
www.rfmd.com.

RS No. 255

Single-chip RF Transceiver

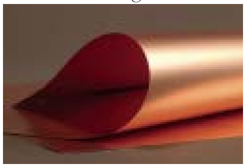
The model SW3200 is a single-chip CMOS, multi-band WCDMA/EDGE (WEDGE) RF

transceiver that supports downlink data rates up to 10.2 Mbps with high speed downlink packet access (HSDPA) category 9 operation. The SW3200, an RF transceiver in Sirific's NEXUS™ III 3.5G product family, incorporates its low noise, wideband direct up-/down-conversion architectures and patented frequency synthesizer design. These advanced CMOS RFIC architectures, coupled with the application of digital CMOS design techniques, enable the SW3200 to achieve the highest levels of integration and WEDGE performance with a reduction in current consumption. The result is a low power, high performance CMOS WEDGE RF transceiver that features a low PCB component count.
Sirific Wireless Ltd.,
Richardson, TX (519) 747-2292,
www.sirific.com.

RS No. 256

MATERIAL

High Frequency Circuit Material



The RO4350™ series high frequency circuit material is a glass-reinforced hydrocarbon/ceramic thermoset laminate set designed for performance sensitive, high volume commercial applications. These laminates are designed to offer good high frequency performance and low cost circuit fabrication. The result is a low loss material, which can be fabricated using standard epoxy/glass (FR4) processes.

Rogers Corp.,
Rogers, CT (860) 779-5597,
www.rogerscorporation.com.

RS No. 257

SOURCES

Oven-controlled Crystal Oscillator

The 9633 accelerometer compensated OCXO is a high performance, ultra-miniature ovenized crystal oscillator designed to provide a high stability output. The 9633 is designed specifically for military applications, including navigation, radar and secure communications, where low acceleration sensitivity capabilities are critical to realize low phase noise under vibration. The 9633 has demonstrated sensitivities of less than 2×10^{-11} per g (gamma) over a wide frequency range.

Symmetricom Inc.,
San Jose, CA (978) 927-8220,
www.symmttm.com.

RS No. 258

Coaxial Resonator Voltage-controlled Oscillator

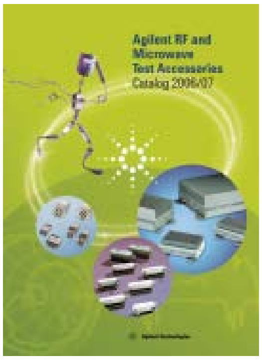
This coaxial resonator based voltage-controlled oscillator (VCO) series includes model CRO2590A (2480 to 2700 MHz) and model CRO2935A (2850 to 3020 MHz) in S-band whereas model CRO3335A (3210 to 3451 MHz) and model CRO3617A (3515 to 3720 MHz) in C-band are all designed to meet the high data rate applications of point-to-multipoint and terrestrial radios as carrier generators. The models offer phase noise performance of –108 dBc/Hz at 10 kHz away from the carrier. The wide band models offer good tuning linearity and harmonic suppression that make them an ideal choice for demanding applications. Size: 0.50" × 0.50" × 0.22". Price: $29.95 (5 pcs min). Delivery: stock to four weeks.

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

RS No. 259

New Literature

Accessories Catalog

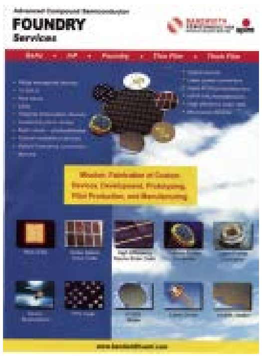


The 2006/07 RF and microwave test accessories catalog enables engineers to quickly research and specify the company's test accessories for new product development and manufacturing needs. The catalog features new product highlights and easy-to-read product selection and comparison tables to help users find the information to meet certain design specifications.

Agilent Technologies Inc., Palo Alto, CA (800) 829-4444, www.agilent.com.

RS No. 200

Product Brochure

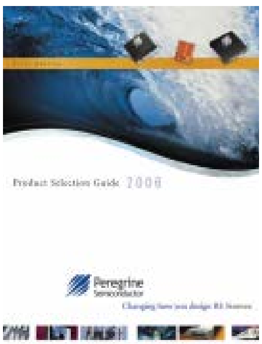


This brochure highlights the company's advanced compound semiconductor foundry services. The company maintains a custom/production wafer-processing laboratory. Capabilities include CAD design of photolithographic mask sets, development of custom device processes as well as routine fabrication processes. Capabilities range from prototype development to full production.

Bandwidth Semiconductor LLC, Hudson, NH (603) 595-8900, www.bandwidthsemi.com.

RS No. 201

Product Selection Guide



This guide provides the company's high performance RF CMOS and mixed-signal communications ICs which are ideally suited for the wireless infrastructure and mobile wireless, broadband communications, space, defense and avionics markets. Manufactured on the company's proprietary UltraCMOS™ technology, the company's product portfolio is poised to meet the demands of the global RF design community.

Peregrine Semiconductor Corp., San Diego, CA (858) 731-9400, www.psemi.com.

RS No. 202

Filter Connector Catalog

The filter connectors featured in this catalog include: the MIL-DTL-38999, MIL-C-26482, MIL-DTL-24308 D-SUB and MIL-DTL-83513 MICRO-D products, together with the ARINC 404, ARINC 600 and EPX series. The publication covers the filter connectors' performance and construction, including typical mechanical and environmental performance, along with termination styles and information on how to order. A .pdf version can be downloaded or a paper copy requested from the company's web site.

Radiall, Rosny Sous Bois, Paris, France 33 1 49 35 35 35, www.radiall.com.

RS No. 203

Solutions Guide

This brochure features the company's Aero® GSM/GPRS/EDGE transceivers. These single-chip CMOS transceivers are designed for multi-band GSM/GPRS/EDGE cellular handsets and wireless data modems. A product description, block diagram, features and applications are also provided.

Silicon Laboratories Inc., Austin, TX (877) 444-3032, www.silabs.com.

RS No. 204

Power Amplifiers Data Sheet

This data sheet provides complete detail on the company's 45 to 65 W Ku-band power amplifiers, the MPC4-1220 series. This series is ideal for SATCOM systems serving military and commercial airborne and mobile platforms. A product photograph, description, performance features, electrical and mechanical specifications, and outline drawings are also provided.

Sophia Wireless Inc., Chantilly, VA (703) 961-9573, www.sophiawireless.com.

RS No. 205

IEEE Radio & Wireless Symposium

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The 2007 IEEE Radio and Wireless Symposium (RWS 2007) will be held in Long Beach, CA, on 9–11 January 2007 as part of the MTT Wireless technical event. In addition to oral presentations and posters, RWS 2007 includes workshops, panels, and a major exhibition. Others collocating in the event are the Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems (SiRF) and the IEEE Topical Workshop on Power Amplifiers for Wireless Communications (PA Workshop).

RWS 2007 sessions will highlight applications including (but not limited to):

- 3G/4G Wireless Communication including Emergency/Location Services
- 802.11/HiperLAN2 Wireless LAN Systems
- Software Defined Radio/Cognitive Radio and other Emerging Technologies
- 802.16/LMDS Broadband Fixed Wireless and Last-Mile Access Techniques
- Broadband Local and Personal Area Networks
- Wireless Sensors and Ad Hoc Networks
- Ultrawideband (UWB) Technologies
- Low-Power/Low Noise RF/Analog IC and System-On-Chip Solutions

Sessions will cover systems and enabling technologies in the areas of:

- System Architecture, Integration, and Convergence Issues
- Digital/Analog Adaptive/Collaborative Signal Processing
- System Level Design, Modeling, and Simulation
- MIMO/Space-Time Processing, Relaying Technology, and Smart Antennas
- Signal Generation/Power Amplification, Linearization, and Active Components
- Front-End Antennas/Subsystems and Passive Components
- Cross-Layer Design

Workshop Proposals

Proposals for workshop topics are solicited, and must be received by 4 June 2006. Details on the process and requirements can be found at www.radiowireless.org.

Paper Submission Instructions

Authors must submit a Summary (not more than 4 pages including figures) electronically using the www.radiowireless.org web page by **5 July 2006**. Authors can indicate their preference for oral or poster presentation format but the Technical Program Committee reserves the right regarding final presentation format decision. Please note that the only accepted file format is pdf.

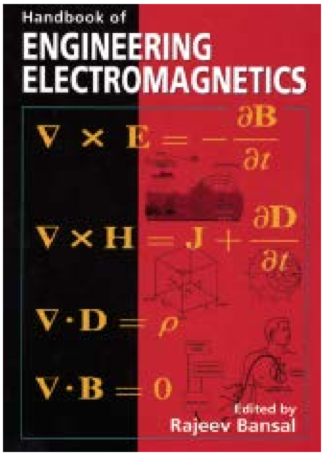
Submissions will be evaluated for originality, significance of the work, technical soundness, and interest to a wide audience. Authors will be notified by 17 August 2006. Final manuscripts of accepted papers (4 pages in length) must be received by **24 October 2006** to be included in the published Proceedings.

Major Exhibition

RWS 2007 is part of MTT Wireless Week which also includes a major commercial exhibition of technologies and services for radio and wireless development. See www.horizonhouse.com for details.

IEEE COMMUNICATIONS SOCIETY

Handbook of Engineering Electromagnetics



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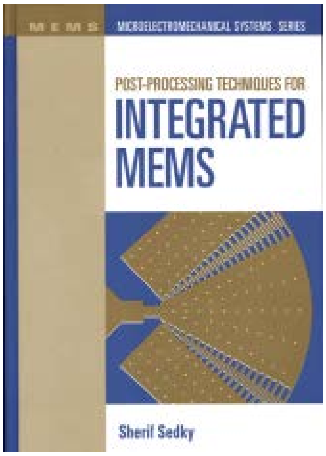
Rajeev Bansal, Editor
Marcel Dekker Inc. • 720 pages; $129.95, £74.99
ISBN: 0-8247-5628-2

This handbook is intended as a desk reference for the broad area of engineering electromagnetics. It should serve as a bridge between standard textbooks in electromagnetic theory, which are comprehensive in terms of theoretical development and specialized references, which often offer detailed lists of formulas, tables and graphs, but do not provide the insight needed to appreciate the underlying physical concepts. Since the handbook is intended to be useful to engineers engaged in electromagnetic applications in a variety of professional settings, the coverage of topics is correspondingly broad in scope. In terms of "fundamental concepts," the book includes coverage of Maxwell equations, static fields, electromagnetic induction, waves, transmission lines, waveguides, antennas and electromagnetic compatibility (Chapters 1 to 10). In terms of "electromagnetic technologies," radar, wireless communication, satellite communication and optical communication are covered (Chapters 11 to 14). Chapter 15 provides an introduction to various numerical techniques being used for computer-aided solutions to complex electromagnetic problems. Given the ubiquitous nature of electromagnetic fields, it is important to consider their biological effects and safety standards (Chapter 16). Chapter 17 presents a concise survey of current and evolving biomedical applications, while Chapter 18 is a review of the techniques used for measuring the electromagnetic properties of biological materials. In terms of "frequency range," this book spans the spectrum from static fields to light waves. Pertinent data in the form of tables and graphs are provided within the context of the subject matter. In addition, Appendices A and B are brief compilations of important electromagnetic constants and units, respectively. Finally, Appendix C is a convenient tutorial on vector analysis and coordinate systems.

Post-processing Techniques for Integrated MEMS



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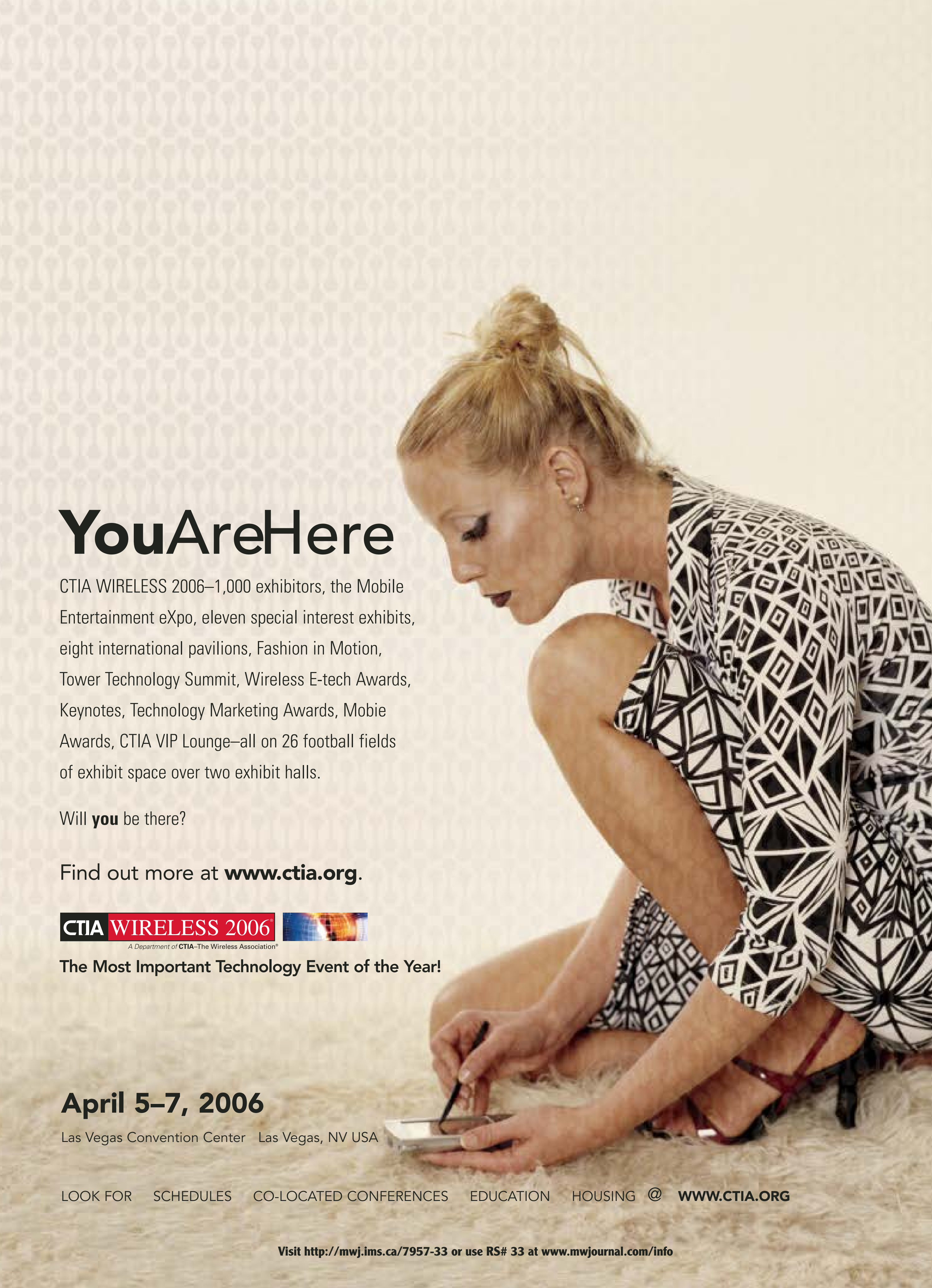
Sherif Sedky
Artech House • 221 pages; $99, £56
ISBN: 1-58053-901-7

The increased demand to implement microelectromechanical systems (MEMS) in a variety of systems requires the monolithic integration of these devices together with the driving and control electronic circuitry on the same chip. This improves yield and reliability, especially for commercial devices in sensitive applications or in applications that require high density integration. The main purpose of this book is to investigate the possibility of developing high quality MEMS structural layers at temperatures compatible with the standard CMOS back end. First, the MEMS fabrication technologies are reviewed. This is followed by defining the maximum thermal budget that can be accommodated by prefabricated standard electronics. Then, the attractive features of the different materials suitable for MEMS are highlighted. The effect of deposition conditions and the type of substrate on the physical properties of the different materials is then discussed. Recently, silicon germanium has gained a lot of attention as a MEMS structural layer that can be processed at CMOS back end temperatures and preserve attractive properties for a variety of MEMS applications. This material is investigated in detail, as it seems to give promise for a simple modular integration process for MEMS on top of standard preprocessed electronics. In addition, low thermal budget techniques that can locally modify the physical properties of the MEMS materials without affecting the underlying layers are introduced. Finally, an overview of the recent developments in the field of MEMS monolithic integration with the driving electronics is given. The advantages and disadvantages of the different approaches implemented either commercially or in academia are highlighted. The milestones on the road to the formation of a generic modular monolithic integration of MEMS with the driving electronics are defined.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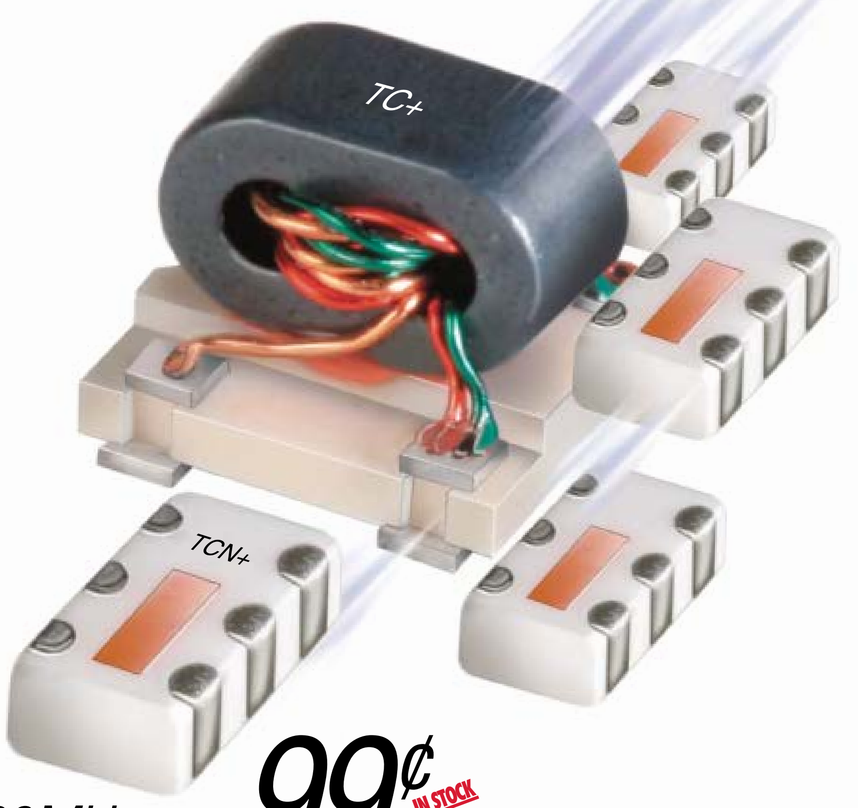

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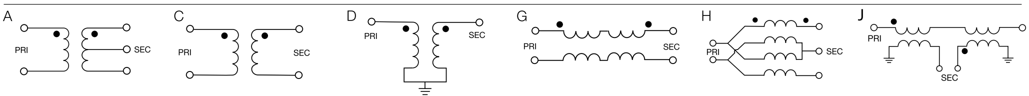

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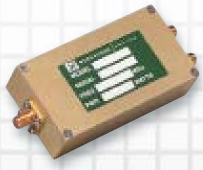

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25 W CW

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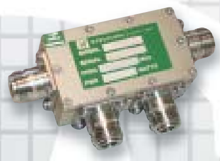
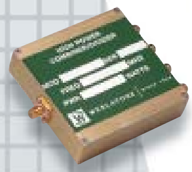
Model C6326
10-2000 MHz
75 W CW





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Model D6405
20-500 MHz
50 W CW

40 dB Dual Directional Coupler
Model C3910
80-1000 MHz
200 W CW

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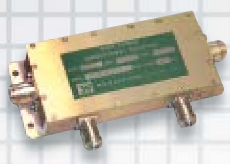

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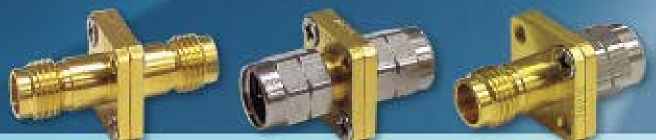

7821A 7821B 7821C

1.85mm – 2.4mm

7824A 7824B 7824C 7824D

1.85mm – 2.92mm

7826A 7826B 7826C 7826D

1.85mm – 3.5mm

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7821C	1.85mm female [1]	1.85mm male [1]	40.0 — 67.0 ≤ 1.15	50 ohm	0.75	(1.905)
7824A	1.85mm female [1]	2.4mm female [2]	DC — 26.5 ≤ 1.06	50 ohm	0.75	(1.905)
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7824C	1.85mm male [1]	2.4mm female [2]	40.0 — 67.0 ≤ 1.15	50 ohm	0.75	(1.905)
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7826D	1.85mm male [1]	2.92mm male [3]		50 ohm	0.657	(1.669)
7827A	1.85mm female [1]	3.5mm female [4]	DC — 4.0 ≤ 1.05	50 ohm	0.657	(1.669))
7827B	1.85mm female [1]	3.5mm male [4]	4.0 — 26.5 ≤ 1.08	50 ohm	0.657	(1.669)
7827C	1.85mm male [1]	3.5mm female [4]	26.5 — 34.0 ≤ 1.12	50 ohm	0.657	(1.669)
7827D	1.85mm male [1]	3.5mm male [4]		50 ohm	0.657	(1.669)

[1] Precision 1.85mm per Maury data sheet 5E-089.

[2] Precision 2.4mm per Maury data sheet 5E-064.

[3] Precision 2.92mm per Maury data sheet 5E-063.

[4] Precision 3.5mm per Maury data sheet 5E-062.

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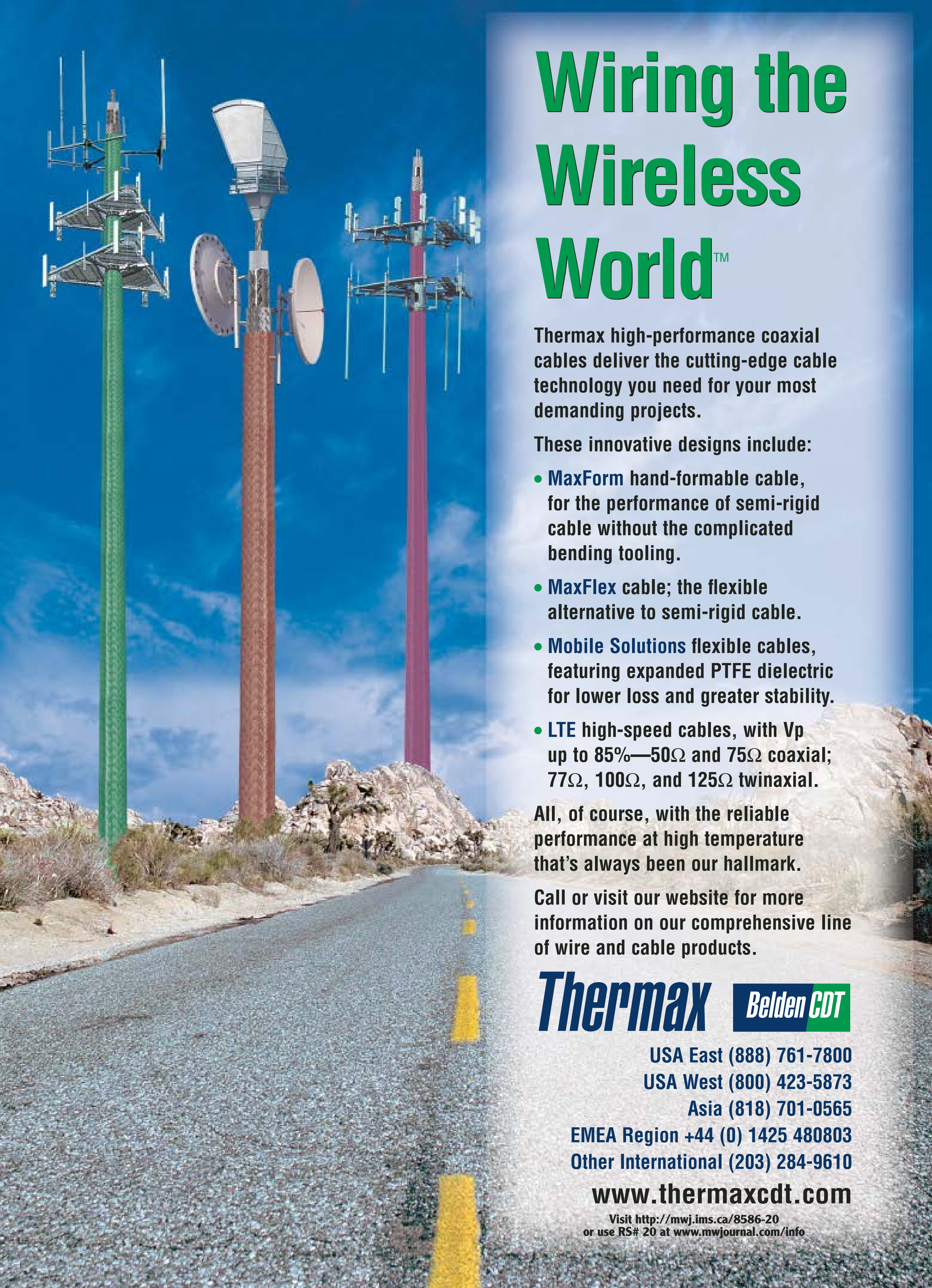
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2006 CONNECTOR, CABLE AND CABLE ASSEMBLY SURVEY

This is the fourth survey of connectors, cables and cable assemblies sponsored by Microwave Journal. *We plan to update it annually with continued industry support and participation.*

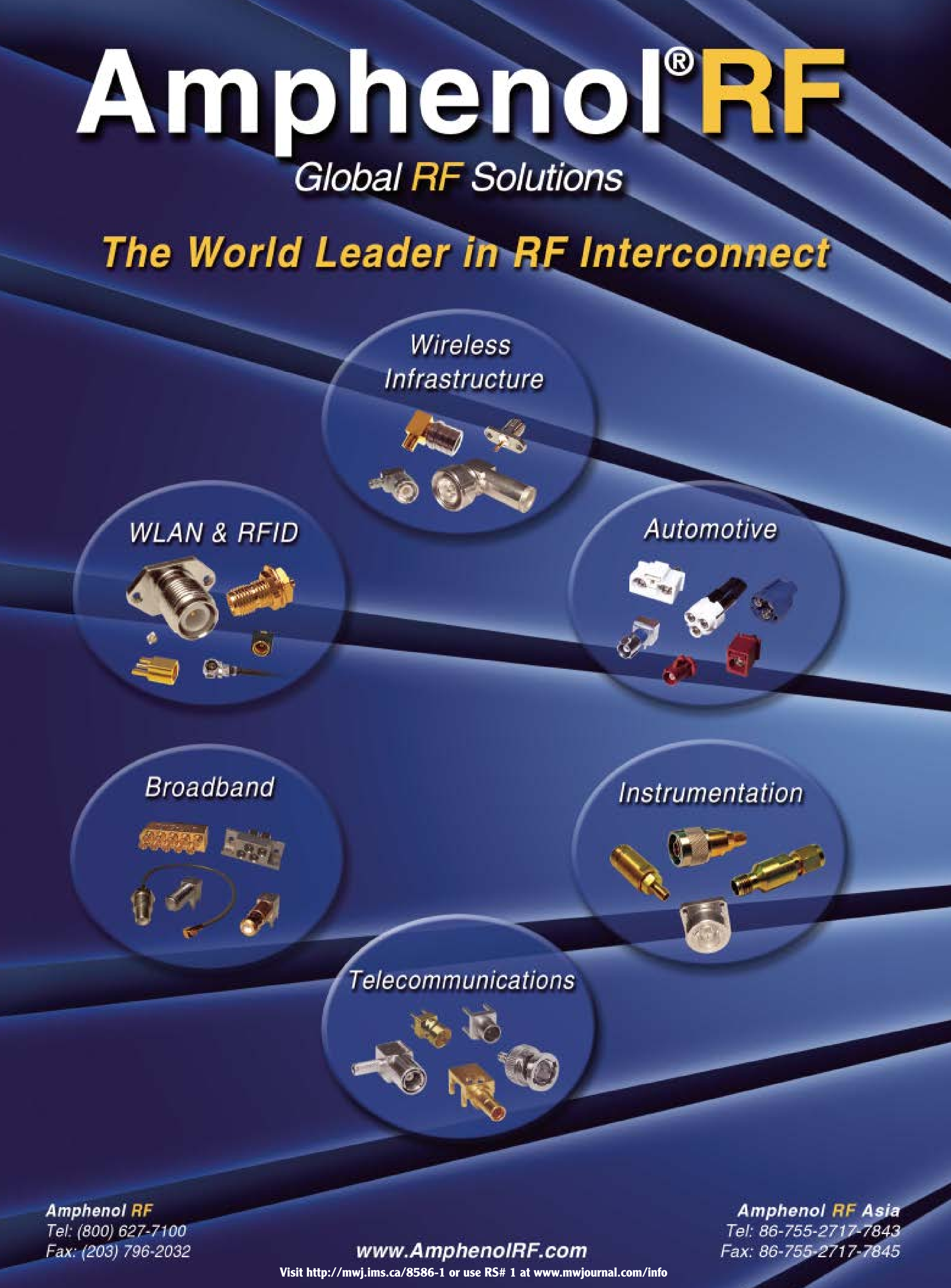
We are very pleased to offer this updated survey of companies providing connectors, cables and cable assemblies. Seventy-four companies responded to our request for information this year, which is an increase from the 68 companies in last year's survey. In addition, 15 of last year's participants have updated their information as well, so this survey represents the most comprehensive listing ever offered of companies providing RF and microwave cable and connector products.

There is clearly a large overlap of similar products being produced by the 74 companies included in the survey, particularly the standard connectors. However, careful examination of the information shows that virtually all of the companies have at least one unique, proprietary or patented product that addresses some niche market and which forms the core of their business, as well as customized products to meet specific requirements. These special products and services seem to be the principal reason for the diversity of suppliers. In addition, some companies specialize in different markets such as Hi-Rel, military and base stations as opposed to low cost commercial and consumer. Thus, in reality, the overlap is not as great as it seems.

Every manufacturer has provided an address for its web site. Most of these sites contain either full catalog information or selected data sheets. We have also provided phone and e-mail points of contact for each company where available. In some cases, both foreign and domestic contacts have been provided.

I would like to thank the many people who responded to our request for information. Because of limited space, we were not able to use some detailed information that was sent in addition to the specific survey answers, however, we were able to use some of that information to expand on the brief answers to the questions. The data are presented in table format on the following pages. Readers are encouraged to use the web information and contact points to gain additional insight on the products, services and capabilities of a company of interest.

HARLAN HOWE, JR.
Editor, **Microwave Journal**



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Company	Standard Connector Types	Special Connectors	Raw Cable Manufacturing
Aeroflex/Weinschel	Planar Crown® and Planar Blind-mate® systems, which are compatible with N, TNC, GPC-7, 3.5 mm, 2.92 mm and 2.4 mm series	Planar Crown® and Planar Blind-mate® allow connector interfaces to be changed for custom applications or for damage replacement	Do not manufacture cable
Aliner	MMCX, MCX, SSMB, SSMA, MC card, SMP, SMA, QMA, SMB, SMC, TNC, BNC, N	MMCX switch connector, MCII, SSMCX, board-to-board connectors, ACX board-to-board	Do not manufacture cable
Amphenol RF	MMCX, AMC, MCX, SMB, SMC, SMA, 1.0/2.3, QMA, FAKRA, BNC, TNC, Mini BNC, Twin BNC, Triax, UHF, Mini UHF, N, F, 7/16	SMP, AFI, QMA, FAKRA, AMC	Yes, please visit www.amphenol.com
Anritsu	K series (2.92 mm), V series (1.85 mm), W1 Connector (1 mm)	Over 300 special or custom designed connectors	Do not manufacture cable
Applied Engineering Products	SMA, SMB, SMC, SLB, SSMB, SSMC, SSLB, SSMA, MCX, 75 Ω MCX, MMCX, 75 Ω Snap-on, 75 Ω Screw-on, BNC, TNC, N, adapters between series and over 100 styles of MIL-PRF-39012 QPL connectors	Water-proof and weather-tight, special leg configurations for PCBs, special plating and finishes, custom contact configurations, special cable types, connectors with internal functions like switches, unique captivation, reverse polarity, special testing	Do not manufacture cable
Astrolab Inc.	N, SMA, SMP, SMPM, TNC, ATNC, 3.5 mm, 2.9 mm, 2.4 mm, 1.85 mm, BNC, 7 mm, 7/16, BMA, TK, SC, HN, M39029 coax contacts – in various forms such as straight, right angle, swept bend, bulkhead and flanged	SMA designs up to 27.5 GHz, SSMA designs up to 40 GHz, low IM space qualified TNC, multipaction resistant designs, Flouraloy dielectric, M39029 contacts up to 12 GHz, phase shifter/line stretchers up to 26.5 GHz, HF hermetically sealed	0.041 to 0.310 diameter from 70% VP to 82% VP, semi-rigid to highly flexible with capability up to 90 GHz
Atlantic Microwave	SMA, SMP, SSMP, 2.9 mm, 2.4 mm, 1.85 mm, N, TNC, BNC, MCX, MMCX, SMB, SMC	Special body lengths, special PCB connections, moisture ingress protection, special cable types	Semi-rigid, copper, aluminum, tin-plated, reformable, flexible, composite, commercial RG-types, bulk and assemblies, telecommunications, Satcom, cellular, base station, industrial
Aviel Electronics Div. of RF Industries	See RF Industries listing	Special designs for non-standard types such as hermetically sealed, low PIM, polarized special interface for compliance with FCC 15.203, blind mate, hermetic rt. angle, 45°, custom make to order capability	Do not manuufcture cable
Belden Inc.	Do not manufacture connectors	Do not manufacture connectors	Mil-Spec RG type coax for high frequency applications as well as 50 Ω antenna coax for wireless communications applications including base stations, wireless LANs and other in-building wireless applications
BTC Electronics Inc.	BMB, BNC, C, G874, GHV, HN, LC/LT, MCX, MHV, MMCX, MQD, N, QDS, QMA, SC, SMA, SMB, SMC, TNC, TPS, TRB, TW34, TWBNC, UHF, 1.0/2.3, 7/16	Special connector configurations to customer's drawing	Do not manufacture cable
Cable Experts Inc.	No standard connector products	No special connectors	Do not manufacture cable
CE Precision Assemblies Inc.	No standard connector products	Special designs for specific customer problems such as a 600 W version of the SMP connector. The company also builds radiation hardened connectors, high temperature and high power connectors as well as low IM and waveguide connectors	Semi-rigid and special cables
Coax Co. Ltd.	SMA, SSMA, N, TNC, BNC	SMA for 0.013" (0.33 mm) diameter cable	Semi-rigid from 0.013" to 0.379" and impedances from 7 to 122 Ω. Combinations of materials such as: niobium, cupronickel, stainless steel, beryllium copper, etc. PTFE, PFA, PE dielectric cables, triaxial cables, alluminum jacketed cables
Compel Group	1.0/2.3 and 1.6/5.6 – 50 or 75 Ω, SMA, SMB, SMC, BMA, SMP, MMCX, MCX, N, 7/16, BT-43, DIN41612, PCMCIA, BNC, Metric 2.0 & 2.5, D-SUB, adapters, terminations and dust covers, singlemode and multimode optical connectors	Special designs are available using a wide variety of materials and processes	Do not manufacture cable but does re-sell under some circumstances
Corning Gilbert Inc.	GPO (DC to 26.5 GHz), GPPO (DC to 65 GHz), GMS (DC to 23 GHz)	Custom versions of the GPO, GPPO and GMS designs for backplane mounting, waveguide launches and group mating configurations	Do not manufacture cable
Delta Electronics Mfg. Corp.	N, 7/16, SMA, 27 GHz SMAs, SMK, SMP, MMCX/MCX TNC/BNC, 1.0/2.3, MHV, C, HN, QDS, G874, YPS, TRB, LC/LT, Mil-PRF-30912 & Mil-PRF-55339	QDS, slide-on, BMA, pressmounts, Mini QDS, G874	Do not manufacture cable
Deutsch Advanced Interconnect	DPP series of connectors in N and SMA configurations with push-pull coupling, 7/16, circular multi-pin, blind mate, environmental power connectors, fiber optic	Custom connectors for special environmental interfaces	Do not manufacture cable
Dynawave Inc.	SMA, SSMA, SMB, SMC, MCX, MMCX, BMA, BMA miniature, SMP, SMPM, SMPSM, SMT, 2.4 mm, 2.92 mm, 3.5 mm, 7 mm, N, TNC, SC, HN, BNC, 7/16	Custom designs for cables, field replaceable, PCB mount, edge mount, hermetic connectors and seals, tabbed contact, adapters	Semi-rigid and flexible as well as custom designs
Electronika International Inc.	BNC, TNC, FME, SMB, SMC, UHF, 3.5 mm, SMA, N, MMCX, MCX, LC, GR874	Special testing and matching	Do not manufacture cable
ESM Cable Corp.	Do not manufacture connectors	Do not manufacture connectors	Do not manufacture cable
EZ Form Cable Corp.	MCX, MMCX, BMA, SMA, SMB, SMC, N, TNC, BNC, SSMA, SSMB, 7/16, DSB	EZ Quick-Connect™ plug (SMA compatible), standard series to stripline and microstrip transitions, standard series for low loss and custom cables	Semi-rigid cable from 0.020 to 0.325 inch in copper or aluminum at impedances from 25 to 100 Ω. Custom cables from special materials, flexible cable such as EZConformable in diameters from 0.034 to 0.250 inch at 50 and 75 Ω, EZFlex 401, 402 and 405 flex
Flexco Microwave Inc.	LC, LT, GPO, BNC, EIA, HN, precision N, precision SMA, SC, SMC and TNC	Special connectors for use on cable assemblies such as GPPO, SSMA and ZMA types	Custom cable is manufactured for use in Flexco cable assemblies
Florida RF Labs Inc.	Do not manufacture connectors	Do not manufacture connectors	Do not manufacture cable

Cable Assemblies	Unique Products	Web site and Contact Information
Do not manufacture cable assemblies	US and international patents on both Planar Crown® and Planar Blind-Mate® systems	www.aeroflex-weinschel.com Technical: Jimmy Dholoo, Sales: Thomas Steidel, sales@aeroflex-weinschel.com
General purpose and military for RG178, RG174, RG316, Filotex, LMR, Belden, flexible, semi-rigid	Specials and cable assemblies	www.aliner.com.tw Technical: Victor Chou, victor@aliner.com.tw
Flexible, semi-rigid, conformable, harnesses, phased matched, time delay	AFI Interface to compensate for axial and radial misalignment, which is available in both 50 and 75 Ω	www.amphenolrf.com Technical: Tom Aubin 203-796-2059, taubin@amphenolrf.com, Sales: Greg Straiton 203-796-2079, gstraiton@amphenolrf.com
Cable assemblies with APC, N, K, V and W1 connectors, mostly semi-rigid. Test cables both armored, semi-rigid and flexible	The new W1 connector, which can be used up to 250°C, VP series Blind Mate up to 65 GHz	www.us.anritsu.com 1-800-Anritsu
Flexible, conformable, semi-rigid, phase matched and delay lines	SLB/SA patented self aligning PCB to PCB system	www.aep.us, Technical: Dave Critelli at dcritelli@aep.us, Sales: Dennis Flanders at dflanders@aep.us, General: sales@aep.us
Mini-bend flexible, convoluted semi-rigid for superconducting temperatures down to 4°K, high flexcables for gimbles and phase stable cables up to 60 GHz	Mini-bend cable assemblies, ever-flex cable and the Cobra-flex line	www.astrolab.com Mary Ceres 732-560-9570
Laboratory and test, general purpose, flexible, semi-rigid, phase stable, phase matched, high temperature	Ultra flexible high frequency, reformable, semi-rigid and flexible test cable are in stock	Joanna Bolton www.atlanticmicrowave.co.uk
Both standard and non-standard types, phase matched, semi-rigid, general purpose, commercial and military	Special fabrication for unique customer applications	www.avielelectronics.com Jack Kaufman 702-739-8155, avielconn@aol.com
Do not manufacture cable assemblies	Conformable™ coax for semi-flexible replacement of rigid-coax	www.belden.com Technical Support: 1-800-belden1
Do not manufacture cable assemblies	Special configurations and quick samples	www.btcelectronics.com Technical: Robert Barnett at rbarnett@btcelectronics.com, Sales: Audra Starling at astarling@btcelectronics.com, 800-526-2828
A large array of RF cable assemblies	CXP1318FX series, low loss RG8/U assemblies	www.cablexperts.com – Marc Abramson, Chuck Abramson
A wide range of custom cable assemblies including build-to-print and custom standard and low loss assemblies from DC to 65 GHz with limited capability to 110 GHz. Cable assemblies are available from commercial grade to space qualified, radiation hardened	All products are unique to the individual customer's requirements. Many are not available for export without government permission	www.cepainc.com, Technical: Henry Richards 480-940-0740 x222, hrichards@cepainc.com, Sales: Kathy Kennard x219, kkennard@cepainc.com
Semi-rigid, low temperature (cryogenics), superconducting, high temperature, medical, telecom, commercial, laboratory and test	Small diameter cables using materials mentioned, polymide dielectric cable, semi-rigid probe cable using phosphor bronze or oxygen free copper. Soldering connector attachment on niobium and stainless steel is a unique technique	www.coax.co.jp/english/index.html Contacts: USA: Mike Cahill, Pete Alfano 978-456-9184 or 9186 info@responsemicrowave.com. Outside of USA: Satoshi Tanabe +81-15-572-3300 stanabe@coax.co.jp
Coaxial, multi-pin, fiber optic, semi-rigid, conformable, corrugated, flexible, multi-strand for commercial, military, laboratory and medical applications	Most comprehensive line of 1.0/2.3 connectors, adapters and cable assemblies. Patented plastic flange 7/16 (available in pms colors)	www.compel.it or www.responsemicrowave.com Contact: Peter Alfano 978-458-9186 or 9184 info@responsemicrowave.com
Laboratory and test, general purpose, semi-rigid, flexible	The GPO and GPPO push-on interconnects were created by Gilbert and are patented	www.corning.com/corninggilbert Technical and Customer Service (US and Canada): 800-651-8869 (International): (01)623-845-5613, push-info@corning.com
Do not make cable assemblies	Heli-grip, QDS, mini QDS, G874	www.deltarf.com Corinne Rose (Application Specialist), crose@deltarf.com and Terry Hannan, thannan@deltarf.com
Laboratory and test for push-pull N and SMA, assemblies to customer specs, test jumper cables with DPP on both ends	DPP series is unique as it does not require a special receptacle	www.deutschai.com Chief Engineer is Bryan Harrington, Customer Service Manager is Clyde Farren, Sales & Marketing is Ted Linder 909-791-2600, Fax 909-791-2611
Instrumentation, laboratory and test, semi-rigid, formable, flexible, delay lines, phase stable, phase matched, low IM, high power, rigid	Internal R&D	www.dynawave.com Brian Nothum 978-469-0555, bnothum@dynawave.com
Laboratory and test, general purpose, flexible, semi-flexible, phase matched sets	Quick delivery on flexible specials	www.electronikainc.com Contact: Rick Modi at modi@electronikainc.com
Laboratory and test, general purpose, flexible, rigid, semi-rigid, phase stable, phase matched, high temperature	Specializing in RF and high frequency	www.esmcablecorp.com Greg Garno or David Doo at 209-892-3347
Custom cable assemblies using all of the EZ Form cables	EZ Quick-Connect™ is patented	www.ezform.com Technical: Tom Ricard at tricard@ezform.com Sales: Jeff Buccitti at jbuccitti@ezform.com
Cable assemblies using Flexco cable for commercial, test and military with emphasis on assemblies with very low phase and amplitude changes during flexure. See next column.	Flexco's cable assemblies are unique due to a combination of connectors and special cables with a wide range of jackets, braids and protective armoring. These are extremely rugged, while providing excellent phase and amplitude stability	www.flexcomw.com Bill Bright, Larry Cagno and Dan Beene at 908-850-5800 or dbeene@flexcomw.com
Laboratory and test, general purpose, flexible, semi-rigid, hand formable, phase stable, phase matched, high temperature, space level and custom	Lab-Flex™ cables DC to 46 GHz with 2.4 mm, 2.9 mm, 3.5 mm SMA, precision type N & TNC as well as low cost assemblies for specific frequency ranges with 40% lower loss and shielding greater than 90 dB	www.rflabs.com Jim Walker 772-286-9300 or jwalker@rflabs.com

Company	Standard Connector Types	Special Connectors	Raw Cable Manufacturing
Florida RS Technology	SMA, TNC and N with special strain relief	Special SMAs in plug, jack and bulkhead	Do not manufacture cable
Gigalane Co. Ltd.	2.4 mm, 2.92 mm, SMA, high performance SMA, SMB, MCX, MMCX, N, GPO	Customer specific designs are available	RG cable types, semi-rigid and special types
Harbour Industries	Do not manufacture connectors	Do not manufacture connectors	20 types of MIL-C-17 QPL approved RG cables, SB strip braid, CN communication network, LL low loss, SS spiral strip, SC sureform, HPF high performance foam, HIS high strength, TRX triaxial, LN low noise, plenum
HoSung Technics Co. Ltd.	MMCX, MCX, SMA, SMB, SMC, BNC, TNC, N, 7/16 DIN, adapters	Special products as requested	Do not manufacture cable
Huber + Suhner	1.0/2.3, 7/16, BMA, BNC, BNO, BNT, MCX, MHV, MMBX, MMCX, N, PC2.4, PC3.5, PC7, QLA, QMA, QN, SHV, SK, SMA, precision SMA, SMB, SMC, SMS, TNC, adapters	Custom MMBX, SUHNER QUICK-FIT, ARC series for automotive applications, quick lock connectors and adapters, phase trimmers	Standard RG types (58, 174, etc.), low loss RF cables, high temperature and flame-retardant, low noise for test applications, triaxial, twisted pair, multiple cables in the same jacket, radiation hardened
IMS Connector Systems GmbH	SMA, SMB, SMC, SMS, SSMB nano, SMP, SMM, MMCX, MCX, coaxial inserts DIN 41612, coaxial inserts sub-D, high power inserts, FME, BNC, TNC, N, 7/16, 1.6/5.6, SMBA (FAKRA Std.), antenna switches	New QLS (quick lock) as well as customer specific designs are available	Do not manufacture cable
Insulated Wire Inc.	SMA, TNC, N, SC, 1.85 mm, 2.4 mm, 2.9 mm, 3.5 mm, 7 mm	Custom designs including MIL 38999 multi-pin contacts, custom flange mounts, special interface connectors	Over 150 types ranging in size from 0.050 to 0.500" with impedances from 10 to 125 Ω. A wide variety of outer braids, shields and jacket materials. Multiple cables in common jackets and armored types as well as semi-rigid and reflex cables
Isotec	SMA, SSMA, SMB, SMZ, SSMB, SMC, SSMC, BNC, TNC, MCX, MMCX, N, 7/16 DIN, field replaceable SMA, reverse polarity and reverse thread, adapters	Slide-on, waterproof, special leg or board, cable types	Do not manufacature cable
Jyebao Co.	SMA, K, SMB, SSMB, SMP, FME, 7/16, SMC, MMCX, MCX, BNC, TNC, N, HN, C, SC, SHV, MHV, plus reverse polarity versions	Custom designs can be made	Semi-rigid and flexible, 0.034, 0.047, 0.085 and 0.141 with various platings
M/A-COM (Tyco)	SMP, 2.4 mm, SSMA, 2.92 mm, 3.5 mm, SMA, SMB, SMC, TR, TNC, BNC, GPO, GPPO, MCX, OSSP, OSP, MMCX, ETNC, N, 7 mm, SC, C, 7/16 IEC, HN, LC, LT, MLT, 7/8 EIA, 1 5/8 EIA (types N, TNC and 7/16 IEC available with low PIM), 3 1/8 EIA	MTNC – A multipactor free variant of TNC for high power space applications, size 8 and 12 contacts for low loss, low VSWR, high frequency performance for MIL-C-87104 and MIL-T-81490 in standard MIL-C-38999 housings, SL family of connectors	Hundreds of cable types from 0.05" to 1.40" with a variety of materials. Military airborne, space satellite, mobile mast, general lab, gimble, lightweight military, commercial aircraft, kapton and halogen free. Custom designs
Maury Microwave	1.85, 2.4, 2.92, 3.5, QT3.5, 7 mm, MPC8, N, TNC, BNC, HN, SC, C, LCP/OSP, 14 mm, 7-16, precision and high precision grades, 75 Ω N and BNC	Quick test 3.5 connectors in different sizes, turns and nut configurations, improved LCP/OSP for high repeatability	Do not manufacture cable
MegaPhase Inc.	Do not manufacture connectors	Special adapters for test applications	GrooveTube™ coaxial cable but do not sell raw cable
Meggitt Safety Systems	SMA, TNC, ETCN, N, 2.4, 2.92, 3.5, GPO, SMP, SC	Custom high frequency e.g. 50 GHz 2.9 mm, special military e.g. multiport, extreme environment e.g. non-magnetic, high temperature e.g. special alloy	Semi-rigid silicon dioxide dielectric cables
Micro-Coax Inc.	Manufacture connectors to support in-house cable assembly business only	Special connectors for multi-paction sensitive applications and low PIM requirements	Semi-rigid, aluminum jacketed, hand-formable-tin dipped, low loss and ultra-low loss flexible, miniature low loss, ultralight flexible
Micro-Mode Inc.	MSMA compatible to SMA 2.92, MBMB compatible to BMB, MMSP compatible to SMP, MSSP compatible to MSMP, MSSS,™ MM4S, TNC, SMA, SSMA, 2.92, 2.4, SMP, SMPM	Special applications with interface to SSMA, BMA, 2.4, SMC and TNC as well as customer interfaces	Do not manufacture cable
Microstock Inc. (Distributor)	SMA, SMB, SMC, MCX, MMCX, MMBX, 3.5 mm, 2.9 mm, 2.4 mm, 1.85 mm, BMA, QMA, SHV, MHV, N, 7/16, 1.0/2.3, 1.6/5.6, 4.1/9.5, TNC, BNC, UHF, plus between series adapters	Special SMAs for low loss 0.047 diam. semi-rigid cables such as UT-47-LL and UT-47-LL-TP, special SMA for 25 Ω 0.090 diam. cables such as UT-90-25 and UT-90-25-TP	Do not manufacture cable, but do distribute it
Microwave Distributors Co. (Midisco)	SMA, SMB, SMC, CMS, SSMA, SSMB, SSMC, MMCX, N, UHF, C, HN, 7/16 and others	Specials and custom products with reasonable minimum lot sizes	Semi-rigid (SNAKE and hand-formable) (Ultra-Flex) as well as distribution of cable from other manufacturers
Midwest Microwave	SMA, SSMA, SMM, BNC, TNC, TNC-A, N, BMA, QPL, 7 mm, 3.5 mm, SC, HN, SMB, SMC, 2.9 mm, BSAs and in-series adapters	Engineering and design support for specials with our sister division, Johnson Components	Do not manufacture cable
Mini-Circuits	Do not manufacture connectors	Do not manufacture connectors	Do not manufacture cable
Molex Inc.	MMCX, MCX, SMB, SMA, SMA field replaceable, SMP, 2.92, BNC, TNC, F, FAKRA, N, 7/16, between series adapters	Catalog derivative for special requirements such as: solderless edge mount, 45 degree SMB plugs, MCX custom coaxial headers	Do not manufacture cable
New and Forever	Low cost standard RF connectors	No specials	Semi rigid in sizes from 0.047" through 0.250" in both copper and aluminum with various plating, center conductors and impedances. Hand-formable, tin soaked in sizes from 0.047" to 0.250". Custom semi-rigid
Radiall	BNC, BMA, coaxipack 2, coaxi-kit, DIN 1.02/2.3, DIN 1.6/5.6, DTF, FME, FAKRA II, HN, mini UHF, microswitch, MC-CARD, MCX, MMCX, N, N7/16, PR, SMA, SSMA, SMB, SSMB, SMC, SMP, SMP commercial, SMB carlock, triax, twinax, TNC, UHF, USCar, adapters	QMA, QN, MMBX, MMS, MMT, MiniQuick, non-magnetic connectors, IMP, UMP, SNB lock	Low loss and ultra low loss raw cable
RF Industries Inc.	3.5 mm (DC to 34 GHz), MHV, reverse polarity N, BNC, TNC, SMA, SMB, SSMB, MMCX, (FCC Part 15 compliant), reverse thread N, TNC, SMA (FCC Part 15 compliant), 7/16 DIN, 75 Ω BNC, TNC, Mini-SMB and SMB, F, FME, mini-bayonet, MCXMMCX, N, NEC P300, RCA, SMA, SMB, TNC, UHF, mini-UHF, unidapt, 1.0/2.3	Unique interface connectors to satisfy FCC Part 15 including reverse polarity, reverse thread, metric thread of modified body connectors. Panel mount N, SMA, TNC with extended dielectic and contacts, custom PCB connectors	Do not manufacture cable

Cable Assemblies	Unique Products	Web site and Contact Information
40 GHz test cables, low loss assemblies, semi-rigid configurations, Flex cables both standard and armored, sizes from 0.019 to 2 inches in diameter	Many of our assemblies are made on patented production equipment	www.flrst.com Technical: Tim Spacek & Al Ragl, Sales: Sandy Struthers, 772-221-8188
Low loss assemblies up to 40 GHz, semi-rigid and semi-flexible types, RG types	VEREND high performance and launch connector	www.gigalane.com Richard Song at sales@gigalane.com
Source of cable for many cable assembly houses	Many of the specialty cables incorporate proprietary materials and processes	www.harbourind.com John D. Palasciano at jpalasciano@harbourind.com
Flexible, semi-rigid and jumper cables	Quick delivery on specials within one week	www.hstcns.com – Anthony Ham at 82-32-683-8007 x216
Flexible RF, form stable, semi-rigid, hand formable, flexible MW	MMBX board-to-board, Sucoflex,™ LSFH (low smoke halogen free), enviroflex cables, low noise cables, triaxial, twisted pair (up to 100 Ω)	www.hubersuhner.com Local sales offices in 60 countries
Semi-rigid, semi-flexible, flexible, corrugated, coilcord, GPS cable, GSM cable, FAKRA cable	Press-fit and press-in as well as MIM manufacturing technology, miniature antenna switches and quick lock connectors	www.imscs.com Sales: Chris Hoy (UK) 0044/2392 75 00 11 sales@imscs.com
Low loss cable assemblies up to 65 GHz, general purpose and laboratory, medical and military applications	Proprietary dielectric of laminated, expanded or full density PTFE. Dielectric constant can be tailored anywhere from 1.3 to 2.0. Patented connector design for full captivation on large cables up to 18 GHz	www.iw-microwave.com Cable assemblies: 203-791-1999 or iwsales@iw.com Raw cable: 631-981-7424 or iw-microwave.com
Flexible, semi-rigid, semi-flex, corrugated UFL cable general purpose, commercial, phase matched, delay lines		www.isoconnector.com Edward Lee at 408-351-3450, isotec@unitel.com.kr
RG types, Japanese types, semi-rigid, handbendable, low loss, phase matched	Almost the only manufacturer of semi-rigid cable in Southeast Asia. Standard connectors are stocked and can be shipped within one week	www.jyebao.com.tw Jyebao Sales – pol-heyns@jyebao.com.tw
Laboratory, general purpose, airborne EW, phase stable, phase and amplitude matched, small diameter, radiation resistant, cable sets with interchangeable ends and replaceable heads, high shock for launch vehicles, space qualified	All products designed and produced in-house	www.macom.com, Technical: Ray Schwartz at 978-442-5487 schwartz@tycoelectronics.com. Sales (Americas): 800-366-2266, (Europe, Middle East, Africa): 44 (1908) 574200, (Asia/Pacific): 81-44-844-8296
Semi-rigid assemblies in general purpose type N as well as precision 2.4 mm, 3.5 mm, SMA, 7 mm, and N in 0.25, 0.141 and 0.085 diameter cables. Test port adapters and between series adapters as well as test cable kits	Quick test connectors and assemblies	www.maurymw.com/mmc_catalog/mmccatalog.htm Technical: Brian Wolf at bwolf@maurymw.com Domestic Sales: Shawna Johnson at sjohnson@maurymw.com Int'l Sales: Anita Luther at aluther@maurymw.com
Flexible and semi-rigid assemblies for test and system cable applications from 2 to 65 GHz. There are five product lines for test and measurement and eight product lines for system and general purpose cables	GrooveTube™ is unique to MegaPhase	www.megaphase.com Technical: Bob Fisher 570-424-8400, bfisher@megaphase.com Sales: Joe Carbonara at 570-424-8400, sales@megaphase.com
Semi-rigid silicon dioxide dielectric cables and assemblies – phase stable from near 0K to 2400 F, phase matched, high temperature, harsh environments and precision configured assemblies	Meggitt is the only company to produce space qualified SiO_2 cables and assemblies	www.stablecable.com Cyril Berg at 805-584-4100, cberg@safetysystem.com
Test, general purpose, flexible, semi-rigid, phase stable, phase matched, high temperature, low loss, ultralight, space qualified	Flexible Ultralight UTiFLEX cable assemblies using DuPont's ARACON™ metal clad fibers	www.micro-coax.com Sales: Bruce Ash at 610-495-4225 Technical: John Lewis at 610-495-4326
Flexible, semi-rigid and rigid phase matched assemblies	MSSS™ series, which is 20% smaller than MSMP and 40% smaller than SMP. Over 500,000 parts produced	www.micromode.com Technical: Mark Perry 619-449-3844 x25 mperry@micromode.com Sales: Brian Peckham 619-449-3844 x46 brian@micromode.com
Laboratory and test, general purpose, flexible RG, semi-rigid formed to specification, phase stable, low loss rigid assemblies	No unique products	www.microstock-inc.com Technical contact: Dr. Bob Schafer, Sales: Scott Frobese, micrstok@ix.netcom.com, 215-699-0355
Standard RG cables, LMR,™ semi-rigid, ultra-flex, and phase stable assemblies	Unique configurations and combinations supported by a large inventory	www.microwavedistributors/idisco.net Technical: John Summerville, Sales: Mark Laurenti, instock@microwavedistributors.com
Test and measurement, general purpose, mil/aero applications, low loss, std. RG-type patch cords, semi-rigid and semi-flex, phase matched, delay lines Flexform I & II	Flexform I and Flexform II are proprietary cable designs plus low loss and ultra low loss cables	www.midwest-microwave.com Contact: Ruth Fawson, 813-920-0170, fawson@emersonnetworkpower.com or Bill Lavery, 734-429-4773 Bill.lavery@emersonnetworkpower.com
Laboratory and test, general purpose, flexible, phase stable, phase matched	Phase stability over more than 20,000 flexes	www.minicircuits.com Contact: Mini-Circuits Applications 718-934-4500, sales@minicircuits.com
Laboratory, test and general purpose applications using flexible, semi-rigid and triax cable	Solderless Edge Mount is a patented Molex design. Supplied in panels up to 30 BNC receptacles	www.molex.com Technical: Don Gould, Dwaine Robison Sales: Roger Kauffman 317-834-5600 rf@molex.com
Low loss, general purpose, flexible, semi rigid and hand-formable	No unique products	www.newandforever-usa.com On-line sales and service
Flexible RG, flexible low loss ECO friendly (zero halogen and sulphur), semi-rigid, handformable, corrugated (spiral and ringed), SHF ultra low loss for general purpose lab and test, outdoor and air frame or lightweight purposes	QMA and QN (quick lock formula), IMP, UMP, MMT and MMS are patented by Radiall	www.radiall.com Technical: info@radiall.com
General purpose, WiFi and antenna pigtails, wire harness, flexible, semi-rigid, phase matched, pull/tensile tested, Hi pot, sweep tested	Unidapt adapters, pigtails, adapter kits, quick disconnect BNC, F, mini-UHF, N, RCA, SMA and TNC, MB and mini-bayonet, cellular interface adapters and connectors	www.rfcoaxconnectors.com www.rfcables.com, www.rfneulink.com Technical: Connie Jones, Dave McReynolds, Ronnie Rice Sales: Rosa Reynolds, Jesse Fuller all at rfi@rfindustries.com

Company	Standard Connector Types	Special Connectors	Raw Cable Manufacturing
RF TEC Mfg. Inc.	SMA, SMB, SMC, SSMA, SSMB, SSMC, TNC, MCX, MMCX, MCCARD, MS147, N, 7/16	Snap-on/Push-on Slide-on adapters for SMA, K adapters, Push-on N adapters, special thin center pin SMA panel mount plug and receptacle, reverse polarity SMA receptacle with special flange, 18 mm connectors, torque reinforced screwed center pin for N and BNC receptacles, 1" long body 75 Ω SMB receptacle, N bulkhead jack for 1.32 mm double shield coax	Do not manufacture cable
Rhophase Microwave Ltd.	No standard connector products	Custom connectors for special applications such as SMA 10 Ω for a laser application	Do not manufacture cable but are UK agents for Insulated Wire Inc., Harbour Industries Corp. and Haverhill Cable and Manufacturing Corp.
Rosenberger Hochfrequenztechnik GmbH & Co. and Rosenberger of North America	SSMB, SSMC, SMP, mini-SMP, MCX, 1.0–2.3, coax inserts for mini-coax, D-sub coax, DIN 41626, high voltage inserts, DIN 41626 power inserts, SMB, SMG, SMC, QLR-A, FME (SAP), 1.6–5.6, BNC, TNC, UHF, mini-UHF, N, 7/16, microdot, F, high voltage SHV-SHV-NIM, high voltage 4–10, IEC antenna, C, high voltage HN, twinax, 3.5–12/CATV, BNC-twinax, adapters, RF-FAKRA, RPC-N, R-TNC, RPC-7, RT-SP, GHz RPC-3.5, RCP-2.92, RCP-1.85, RCP-1.0, RCP-2.4	SMCC for surface-mount, custom products on request	Do not manufacture cable
S.G. McGeary Co.	1.85 mm, 2.4 mm, 2.9 mm, 3.5 mm, PGM, SSMA, SMA, TNC, N, 7 mm	Custom designs are available on request, including 1.0 mm (DC-110 GHz), 2.9 spark plug over 1-1/2" long, special sraight and angle flange mounts	Do not manufacture cable
Sabritec Inc.	SCX, Micro-D, SMP, SMPM, high frequency D-sub size 8 coax contacts	Custom designs are available on request	Do not manufacture cable
San-tron Inc.	N, 7/16, SMA, BNC, TNC, C, HN, LC, MHV, SC, SHV, UHF, 1.0/2.3 and adapters	Extended insulators and contacts, custom flanges, custom cable sizes, custom designs based on standard interface designs	Do not manufacture cable
Semflex Inc.	MCX, SMA, BMA, 3.5 mm, 2.9 mm, 2.4 mm, 1.85 mm, BNC, TNC, ETNC, N, 7 mm, SC, HN, 7/16 DIN, 7/8 EIA, 1 3/8 EIA, 1 5/8 EIA	High power/high temperature, environmental sealed, custom interfaces, push-on, blind-mate, phase trimmers	High performance 50 Ω, low loss, high power, low density PTFE dielectrics, RG cable types, communications cable, custom cable
Sources East	SMA, SMB, SMC, SMK, SMP, SMZ, SSMA, SSMB, MCX, MMCX, BMA, BNC, TNC, N, 7-16 (L29), CCWX, DSB, DSD, ISMA, 2.92, SMB-75, SSMB-75, SMC-75, MCX-75, SMZ-75, SAA-75, TNC-75, BNC-75, reverse polarity SMA, MCX, TNC and BNC	Special connectors from modified standards with special pin length, shape or termination. Special housings and finishes	Do not manufacture cable
Southwest Microwave Inc.	SMA, enhanced high temperature SMA, N, TNC, SSMA, OPS/BMA, 2.92 mm, 2.4 mm, 1.85 mm, adapters between series, end-launch adapters, field replaceable accessories, new SSMA to 40 GHz and SSMA-to-2.4 mm adapters to 50 GHz	Custom designs are available on request. Waveguide launchers, mechanical switch connectors, special flanges, longer lengths, custom probes, 50% of shipments are non-catalog specials	Do not manufacture cable
Special Hermetic Products	Hermetic SMP (MIL-STD-348)	Modified SMPs for special interface mounting	Do not manufacture cable
Spectrum Elektrotechnik GmbH	1.4/4.4 mm, 1.8/5.6 mm, 2/5.5 mm, 1.85 mm (V), 2.4 mm, 2.92 mm (K), 3.5 mm, 7 mm, 7/16, BMA, BNC, C, HN, N, SC, SMA, SMP, SPPO (SSMP), TNC, TNX, SBX, SBY, SMP, SMPM, SQ-8, SSMA	SPM (Spectrum power miniature), push-ons for 7/16, N, TNC, SMA and SMA reverse sex, SBX (Spectrum blind-mate X), SBY (Spectrum sub sub miniature push-on) phase adjustable connectors. New mitred angle airline connectors and adapters (MA2-line) to 63 GHz. New hermetically sealed connectors and adapters with venting holes for vacuum chamber test and space applications: N and TNC to 12.4 and 18 GHz and 2.9 mm to 40 GHz. High power adapters with venting holes	0.141 semi-rigid cable using a seamless convoluted stainless steel copper composite tubing known as “Handy Form Type 33”
Spinner GmbH	7/16 (low PIM), N (low PIM), 4.1-9.5 (low PIM), TNC, BNC, N, HN, 1.6-5.6 EIA, between series adapters	Custom 7/16 panel mount and EIA connectors with a coupling nut	Do not manufacture cable
SRC Cables Inc.	Do not manufacture connectors	Do not manufacture connectors	Do not make their own cable, custom designed cables are made for them
SRI Connector Inc.	1.85 mm, 2.4 mm, 2.9 mm, 3.5 mm 7 mm, N, SMA, TNC, ZMA and between series adapters	Superites SMA right angle connectors with high performance, proprietary custom designs	Do not manufacture cable
SSI Cable Corp.	Do not manufacture connectors	Stainless steel connectors made to their specifications and specials at customer request	0.093, 0.145, and 0.240 stainless steel cable in regular and low loss types as well as stainless steel jacket over copper outer conductor, PTFE or medium loss dielectric
Storm Products Inc.	SMA, TNC, N, precision N, 3.5 mm, 2.4 mm, GPO, GPPO, GMS, 2.9 mm, 2.4 NMD	Custom designs for specific customer requirements	Semi-rigid, flexible, solid PTFE, low loss low density PTFE, microporous and expanded PTFE, ePTFE tape and foil wrapping, flat and round wire braiding, textile braiding, low and high temperature extrusion, semi-rigid die sizing
SV Microwave Inc.	SMA, SSMA, BMA, BMMA, BMZ, BZ, ZMA, MCX, MMCX, SMP, SMPM, TNC, precision TNC, N, precision N, SMB, SMC, 1.85 mm, 2.4 mm, SVK, 2.92 mm, 3.5 mm, 7 mm, C, SC, HN, 7-16, QDS, LC/LT, EIA, multi-contact assemblies	Custom designs including space qualified, high-rel and multi-contact	Do not manufacture cable
Synergy Microwave	Do not manufacture connectors	Do not manufacture connectors	Do not manaufacture cable
Telegartner Inc.	BNC, TNC, UHF, mini-UHF, N, 7/16 DIN, 1.6/5.6 DIN, FME, SMA, SMB, SMC, SMS, SSMB, MCX, MMCX, ASMB	Custom designs as well as surge protectors (both gas and stub) for N and 7/16, low PIM types, special connectors for corrugated and non-standard cables	Do not manufacture cable
Tensolite Inc.	SMA, SSMA, SMP, SSMP, SSMT BMA, 2.92 mm, 1.85 mm, MCX, MMCX, SMK, 1.85 mm, N, TNC, QBC, HDRFI, 7 mm, TK	HF connectors to 65 GHz, integrated connector block interface assemblies, TK connectors, QBC, HDRFI, custom angle designs	Mil-C-17, low loss coax 70% VP, low loss 77% and 82% VP with helical braid (solid and stranded inner conductors), phase stable 82% VP, low loss semi-rigid

Cable Assemblies	Unique Products	Web site and Contact Information
Laboratory and test, general purpose, flexible, semi-rigid, rigid, phase stable, phase matched, high temperature, 1.85 mm, 1.00 mm, push-on/snap-on	Snap-on and push-on SMA, push-on N up to 14 GHz, long sleeve thumbnut SMA, connectors for 1.32 mm and 0.8 mm cables for Hirose U.FL connectors and cable assemblies	www.rftec.com Contact: Kiyoshi Endo 770-251-2235 or k4st@rftec.com
Laboratory and test to 50 GHz, medical, defense, general purpose, flexible, semi-rigid, phase stable, phase matched	No unique products	www.rhophase.co.uk Technical: Byron Putt & Nick Lewis, Sales: Jodie Di-Orio & Bob Davis
Flexible, semi-flexible, semi-rigid, corrugated, UTIFLEX cable assemblies, test cables	QLR-A (Quick Lock Rosenberger-SMA), SMCC-surface-mount coaxial connector is patented coax to planar technology	Rosenberger GmbH: www.rosenberger.de Europe: Harry Rausch (+49 8684-180) info@rosenberger.de US: Rosenberger of North America: www.rosenbergerna.com Contact: Jihan Mohammed 717-290-8000 x231 jmohammed@rosenbergerna.com
Do not manufacture cable assemblies	Swept right angle bends in all series plus the PGM series, which is intermateable with SSMA connectors up to 50 GHz and uses an air-dielectric interface. New 1.0 mm series extends the capability to 110 GHz	www.sgmcgeary.com Technical: Larry Herring Sales: Steve McGeary 321-409-0509, Jim Riter 973-224-4510 Fax 321-409-0510
RG-316 flexible coax, RG-178 flexible coax, RG-405 semi-rigid, RG-402 semi-rigid, RG-58 flexible coax, SR.047 semi-rigid	SCX-Air dielectric interface	www.sabritec.com/catalogs/catalogdownload.htm Contact: Mike Carlson mcarlson@sabritec.com
Do not manufacture cable assemblies	Reverse polarity types and unique 15 product line to meet FCC Part 15.203	www.santron.com Technical: Fred Hull 978-356-1585, fred@santron.com, Sales: Chris Sanders chris@santron.com
Test and measurement, phase or delay matched, semi-rigid and conformable, rigid air/dielectric electroform assemblies, custom splitters and power dividers, 1553 databus, custom harnesses and corrugated jumpers	High power KW series cable, lightweight RG+ series cable, rigid air dielectric electroform assemblies	www.semflex.com Technical: Robert Thiel Sales: Doug Hartje at doug.hartje@semflex.com
Flexible, semi-rigid, conformable, corrugated and other types	Wide variety with the ability to provide custom designs in small quantities	www.sourceseast.com Wayne Pittman at 408-374-1031, waynep@sourceseast.com
Semi-rigid and semi-flexible/conformable, field replaceable connectors, high-rel, high end for critical applications	All connectors are thermal tested, space qualified materials, high-rel, high temperature performance, lot control and material traceability, lead-free solder processing	www.southwestmicrowave.com Technical: Dusty Leavitt dusty@southwestmicrowave.com Bill Rosas, David Shaff 480-783-0201
Do not manufacture cable assemblies	Robust series for aluminum and kovar as well as other housing materials are covered by US patents or patents pending	www.shp-seals.com Technical: Jack Pollock jack@shp-seals.com Sales: Wendy Cheney wendy@shp-seals.com 603-654-2002 Fax 603-654-2533
Flexible test and measurement, ruggedized, military, interconnect systems, power, commercial RG types, phase stable, hand formable, semi-rigid (0.034" to 0.50" diameter), radiation resistant, general purpose, new high power cable assemblies with vented connectors for vacuum test chamber and space applications	CNCA-700 cable cutting and stripping machine, push-on 7/16, N, SMA, TNC and SNX, SBY, SSPO and SPM are unique, new MA2-line and SA2-line angle air connectors, new hermetic glass beads	www.spectrum-et.com Peter Von Nordheim +49-89-3548-040 pvnordheim@compuserve.com
Corrugated cables for base stations and low IM test, braided general purpose, semi-rigid, phase stable, phase matched	Jumper cables for corrugated copper cables	www.spinner.de info@spinner.de
All types of cable assemblies	Proprietary coax types SRC-316, SRC-402SF & SRC-405SF	www.src-cables.com President: Dan Hirschnitz, dan@src-cables.com Sales Coordinator: Kathy Badger, kathy@src-cables.com
Do not make cable assemblies	Superite series	www.sriconnectorgage.com Mark Hiser 321-259-9688 hiser@sriconnectorgage.com
Semi-rigid (copper, stainless steel, aluminum), flexible, conformable, phase matched, delay lines, medium and low loss, wireless preps, wire harnesses, test, general purpose and cryogenic	Stainless steel cables are unique to SSI	www.ssicable.com Contacts: Bill Smith and Brek Sowers 360-426-5719 bsmith@ssicable.com
Semi-rigid, flexible, general purpose, laboratory and test, military, communications, miniature low loss, phase stable, high-rel, thermal pre-conditioned	Phase Master® – exceptional phase stability with temperature, True Blue® – low loss with durability and value, Storm Flex™ – superior electrical performance, trouble free, durable, compact, Accu-Test® – calibration accuracy, repeatable phase measurement with flex	www.stormproducts.com/microwave Inside sales 888-347-8676
All types built to customer requirements	Custon blind-mate from DC-40 GHz multi blind-mate rack-and-panel types with reduced center-to-center dimensions, waterproof connectors (in both mated and unmated conditions)	www.svmicrowave.com Sales & technical 561-840-1800 sales@svmicrowave.com
General lab test high temperature DC-18 GHz flexible, semi-flexible and ultra-flex with SMA and Type N connectors	Specializes in RF/microwave and durable custom designs	www.synergymwave.com Contact: Chi Man Shum 973-881-8800 x305, shum@synergymwave.com
Laboratory and test, general purpose, flexible, conformable, semi-rigid, low loss, high power corrugated, multi-core coax	SimFIX Plus™ connectors and low PIM telealloy plating	www.telegartner.com Technical: Allen Ehredt Sales: Jim Ziebka 630-616-7600 sales@telegartner.com
Laboratory and test (Workhorse, Workhorse Plus, Workhorse Low Loss), general purpose (Mil-C flexible, BNC assembly), flexible (Q-flex, Q-flex Plus, 40 GHz flexible, 50 GHz flexible), rigid (copper tube), semi-rigid (0.035 to 0.250 copper and aluminum tube) phase stable and phase matched (flexible and semi-rigid)	QBC series for blind mating with standard series, Netflight™ cables, UCCULITE™ cables, Q-Flex,® Semi-Flex® and Workhorse® cable assemblies, high density application cable assemblies such as HDSI® and HDSI-DP®	Wire and Cable: www.tensolite.com/product_documents/ Aerospace%20Wire%and%20Cable.pdf RF Microwave Connectors: www.tensolite.com/product_documents/ RF_Microcatalog%LoRz.pdf RF Microwave Assemblies: www.tensolite.com/product_documents/ Standard%20ctlg.pdf. Contact: Mohsin Peeran & Chris Novak 866-282-4708

Company	Standard Connector Types	Special Connectors	Raw Cable Manufacturing
Thermax/CDT	Do not manufacture connectors	Do not manufacture connectors	MIL-C-17 cables, MaxForm hand formable, MaxFlex cables, high temperature, low loss cables with air expanded PTFE, seamless wrap PTFE tape dielectric cables
Times Microwave Systems Inc.	N, TNC, BNC, SMA, UHF, mini-UHF, 1.0/2.3 DIN, 7/16 DIN, 7/8 EIA, 7 mm, 3.5 mm, reverse polarity	Reverse polarity, self-locking, phase trimmed, non-solder (EZ)	Commercial, aerospace and shipboard high reliability RF & microwave
Trompeter Electronics Inc.	BNC, TNC, N (all 50 or 75 Ω), SMZ, F, mini-BNC (75 Ω), WECO and mini-WECO, TPS, TRB, TRT, TRS, TTM, TRC, TRN, TWBNC	Patching and distribution panels, custom designs, hermetic, radiation resistant, space rated to NASA Srec SP-R-022	Do not manufacture cable
TRU Corp.	2.4 mm, 2.92 mm, 3.5 mm, 7 mm, 7/16 DIN, MCX, MMCX, SMA, SMB, SMC, SMP, BMA, BMMA, BNC, N, TNC, ATNC, C, SC, HN, LC, LT, EIA, TRIAX	Custom high power/high voltage interfaces, polarized, environmental sealed, low PIM, precision adapters, swept high power right angle adapters	High performance, high power/temperature, flexible 50 Ω, low loss, low density PTFE dielectrics, RG cable types, cintru™ communication cable, general purpose RF/microwave
Vitelec Co.	BNC (50 & 75 Ω), insulated BNC, twin BNC, TNC, SMA, SMB, SMC, MCX, MMCX, N, N (high frequency), twinax, UHF, mini-UHF, FME, F, euro, adapters	Modifications of standard product as well as custom designs	Do not manufacture cable
Winchester Electronics	SMA, SMB, SMC, MCX, BNC, TNC, QMA, N, Combo D housings, size 8 contacts	Quick Connect SMA™, Quick Connect N™, customs to specifications	Do not manufacture cable
W.L. Gore & Associates Inc.	7/16, N, TNC, TNCA, SMA, precision N, 7 mm, 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm, MVX, MMCX, BMA, BMMA, #8, #12, SMP, SMPM, adapters between series, blind mate adapters, PCB mount connectors	Special board mount footprints, custom cable connectors, replaceable interfaces	Broad capabilities including coaxial, RF/microwave, round, planar, ribbon, triaxial, and hybrid constructions, fiber optical, industrial, high flex

Cable Assemblies	Unique Products	Web site and Contact Information
Do not manufacture cable assemblies	Thermax LTE expanded PTFE dielectric is proprietary as is seamless wrap PTFE dielectric and jackets	www.thermaxcdt.com Maria Neclerio 203-284-9610
Laboratory and test, general purpose, flexible, semi-rigid, phase stable, phase matched, high temperature	Miltech, blindmate, T-flex, stripflex, T-com, nu-trac, FlexRAD, testmate, phasetrack, LLSB, LSSB, and LMR cable and cable assemblies	www.timesmicrowave.com Technical: Joe Lanoue jlanoue@timesmicrowave.com Sales: Sue Reynolds sreynolds@timesmicrowave.com
1553 data buss and ground support, broadcast head-end patching, Telco central office, medical MRI test, laboratory and test	Separable BNC connectors for PC mount, miniature normal-through patch jacks with true 75 Ω for HDTV performance	www.trompeter.com, Technical: Mark Borton 818-865-6534, mark.borton@trompeter.com, Sales: Dale Reed 818-865-6538, dale.reed@trompeter.com or sales@trompeter.com
High power/high voltage phase and amplitude matched, shipboard and aerospace, flexible, semi-rigid, corrugated and rigid line assemblies, general purpose, cintru™ broadband communication, customized cable/connector attachments	Quick-disconnect line (QD16,™ QDL, QDM, QDS, QRM,™ SQS™), safety interlock interfaces, high temperatuare and frequency dielectric interfaces, solderless right angle cable attachments	www.trucorporation.com Brenda Wheeler, 978-532-0775
Semi-rigid, flexible (with or without data for telecoms, datacoms, wireless, test)	Gigaflex™ cable assemblies	www.vitelec.com.uk sales@vitelec.com.uk +44 (0) 1420 488661
General purpose, flexible, semi-rigid, phase matched, delay lines, wire harnesses	Quick Connect series for use with standard SMA and N jacks without compromising performance	www.winchesterelectronics com Technical: Ron Ciecko 203-741-5484 Sales: Beth Beadle 203-741-5481
Flexible, laboratory and test, phase and amplitude stable, performance options through 110 GHz, ruggedized, general purpose, phase matched, high temperature, low loss, long length, high power, spaceflight, high density, airframe/vapor sealed	Performance to 110 GHz, precision test adapters, excellent phase and amplitude stability, low loss/long length assemblies, industry standard performance	www.gore.com/electronics 800-445-4673 or 302-292-5100

CONNECTOR TORQUE REQUIREMENTS

In the world of RF coaxial threaded connections, too often the efforts of selecting a suitable connector interface, procuring it from a reliable source and manufacturing a high quality assembly are done in vain because the connector has not been tightened to the proper torque value and/or steps were not taken to insure that the connection will be maintained during its application. It is not fair to blame the installer, as sifting through the maze of commercial, military and supplier specific standards can be a daunting task.

The job of a coaxial cable assembly is to transmit the RF signal with as little loss and distortion of the input signal as possible. At low frequencies, the RF connection can be quite forgiving. Anyone who has installed RF connectors for his cable TV has probably seen little degradation to the signal, provided the connection was not open or shorted out. However, as operating frequencies rise above 2 GHz, the quality of the connection becomes increasingly important. The key attribute in creating and maintaining good RF connections is making sure the connector interfaces are fully engaged during the installation and remain so during use. A critical component in this connection is assuring that the connectors are properly mated. This requires knowledge of the installation torque requirements, using torque wrenches calibrated to the proper value for installation and having a method for securing the connectors that assures that they will not become loose. The recommended torque level for threaded coaxial connectors is determined by the size of the connector and the materials from which it is made. As one would expect, smaller connectors have lower torque requirements as well as connectors made of softer materials such as brass rather than stainless steel. The application of insufficient torque will result in a poor or unstable connection while an over torque will damage the mating surfaces and coupling mechanisms. ***Table 1*** summarizes the requirements for some of the common types of connectors.

TABLE I
TYPES OF THREADED CONNECTORS

Types	*Torque (in lbs)*
SMA	7 to 10
2.9 mm	7 to 10
2.4 mm	7 to 10
Standard TNC	12 to 15
Precision TNC	20 to 26
Standard N	7 to 10
Precision N	20 to 26
SC	20 to 26
7-16 DIN	220 to 300

Small diameter connectors, which include the SMA, 2.9 and 2.4 mm types, are used in the highest frequency applications. They are almost always made of stainless steel and rely on surface mating. Mid-size connectors, which include the types N and TNC, are available in more variations to address specific needs. Standard TNC and N connectors are designed for use below 11 GHz and are made of brass, which limits the installation torque that can be applied without damaging the interface and coupling components. Precision stainless steel TNC connectors have been developed to provide reliable connections under extreme conditions and to extend the effective operating frequency range to 18 GHz. The requirements for these connectors are addressed in the MIL-T-81490 and MIL-C-87104 specifications. The installation torque lev-

TED PREMA
Times Microwave Systems
Wallingford, CT

FLEX TEST™ CABLES

DC to 18GHz from $68.95 ea. (qty.1-9) IN STOCK

Strength, ruggedness, and reliability…*supercharged!* That's what you get when you choose Mini-Circuits ultra-flexible precision test cables. Engineered to be a workhorse for your day-to-day test operations, these triple shielded cable assemblies are qualified to at least 20,000 bends, employ an advanced strain relief system, and are equipped with passivated stainless steel connectors, *so you can rely on them to* ***flex, connect and disconnect over and over and over again!*** They're so rugged, each test cable is backed by our 6 month guarantee*! With low insertion loss and very good return loss, you can also rely on getting good performance over the wide DC-18GHz band. Need them right away? Overnight shipment is available. So make Mini-Circuits your test cable connection! *Mini-Circuits…we're redefining what VALUE is all about!*

6 mo. GUARANTEE **Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within **six** months of shipment. This guarantee excludes cable or connector interface damage from misuse or abuse.*

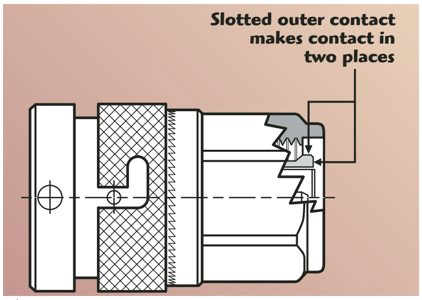
Detailed Performance Specs and Shopping Online at: **www.minicircuits.com/tcables.shtml**

Frequency Range: DC-18GHz, Impedance: 50 ohms

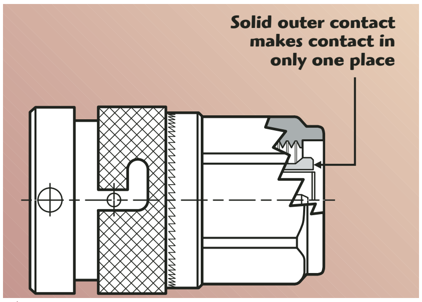
Models	Connector Type	Length (Ft.)	Inser. Loss (dB) Midband Typ.	Return Loss (dB) Midband Typ.	Price $ ea. Qty.(1-9)
Male to Male					
CBL-1.5FT-SMSM+	SMA	1.5	0.7	27	68.95
CBL-2FT-SMSM+	SMA	2	1.1	27	69.95
CBL-3FT-SMSM+	SMA	3	1.5	27	72.95
CBL-4FT-SMSM+	SMA	4	1.6	27	75.95
CBL-6FT-SMSM+	SMA	6	3.0	27	79.95
CBL-2FT-SMNM+	SMA to N-Type	2	1.1	27	99.95
CBL-3FT-SMNM+	SMA to N-Type	3	1.5	27	104.95
CBL-4FT-SMNM+	SMA to N-Type	4	1.6	27	112.95
CBL-6FT-SMNM+	SMA to N-Type	6	3.0	27	114.95
CBL-15FT-SMNM+	SMA to N-Type	15	7.3	27	156.95
CBL-2FT-NMNM+	N-Type	2	1.1	27	102.95
CBL-3FT-NMNM+	N-Type	3	1.5	27	105.95
CBL-6FT-NMNM+	N-Type	6	3.0	27	112.95
CBL-15FT-NMNM+	N-Type	15	7.3	27	164.95
CBL-20FT-NMNM+	N-Type	20	9.4	27	178.95
CBL-25FT-NMNM+	N-Type	25	11.7	27	199.95
Female to Male					
CBL-3FT-SFSM+	SMA-F to SMA-M	3	1.5	27	93.95
CBL-2FT-SFNM+	SMA-F to N-M	2	1.1	27	119.95
CBL-3FT-SFNM+	SMA-F to N-M	3	1.5	27	124.95
CBL-6FT-SFNM+	SMA-F to N-M	6	3.0	27	146.95

Custom sizes available, consult factory.

RoHS COMPLIANT



▲ *Fig. 1 Connector with slotted outer conductor contact.*



▲ *Fig. 2 Connector with solid outer conductor contact.*

el for precision connectors is increased from the standard connector value of 10 to 13 inch-pounds to 20 to 26 inch-pounds. This added torque makes them more suitable for airframe and other high vibration applications.

RF connections require intimate contact of both the inner and outer conductors. The center contacts on all standard connectors rely on one side, normally the female (jack) having a formed spring finger contact into which the male contact is inserted, thus assuring electrical contact. TNC and N connectors are available with either solid or slotted outer conductor contacts. Slotted outer contacts are formed and act as springs, designed to make contact with the base and side walls of the mating connectors, as shown in ***Figure 1***. In contrast, solid outer contacts only make contact at the base of the mating connector (see ***Figure 2***) and although they provide excellent electrical performance and are less costly to produce, they can suffer from severe signal degradation should they become loose during use. Slotted outer contacts are therefore strongly recommended for all applications subject to vibrations.

Large connectors are designed to be installed with high torque levels, thus assuring a secure connection under all conditions. The 7-16 DIN is a connector widely used in the telecommunications industry, particularly where low passive intermodulation or high power handling is required. It is designed to be installed with a torque of 220 to 300 inch-pounds, which is a full order of magnitude greater than for the type N or TNC.

▲ *Fig. 3 Self-locking TNC connector (left) compared to a standard TNC with lockwires.*

▲ *Fig. 4 M8 multiport connector installed in an aircraft.*

MAINTAINING MATING TORQUE

Mated connectors can come loose from vibration if not locked in some fashion. The old and tried method of accomplishing this in airborne applications is by lock-wiring the connector to its mate. The downside of this method is that it is time consuming and the pieces of wire that may be left in the aircraft during the process of installation or removal can damage critical aircraft components. Nearly all modern aircraft have adopted self-locking connectors as the standard for RF interconnects. An example of a TNC self-locking connector next to a traditional lock-wire connector is shown in ***Figure 3***. In this design, the TNC coupling nut is torqued to its required value of 20 to 26 inch-pounds after which the locking mechanism is engaged to prevent the coupling nut from backing off. As a further enhancement, connectors that have self-limiting torque mechanisms can be provided but at a cost of weight and size.

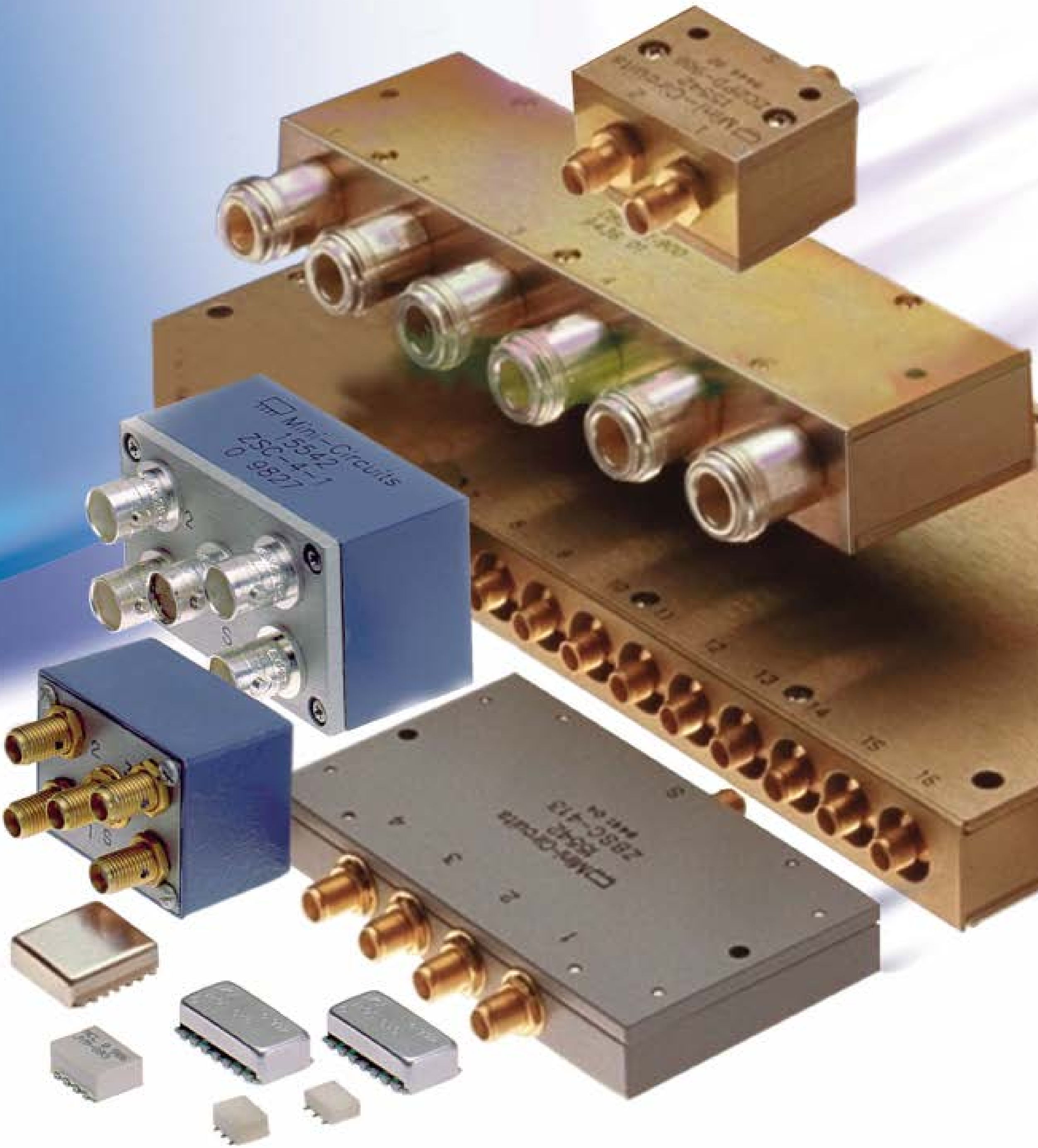
ALTERNATIVES TO THREADED CONNECTORS

There has been an increased interest over the last several years for alternate approaches to threaded RF connections. This interest is being driven by the desire to increase packaging density, reduce weight, decrease maintenance time and improve reliability. Single high frequency RF connections are increasingly being done with bayonet style couplings. The most commonly known types of bayonet mount connectors are the C and BNC, which have been used for many years, primarily for low frequency interconnects. The main problem to be overcome with bayonet designs is that the surface-to-surface mating of the outer contacts relies on the spring force exerted by the coupling mechanism. For low frequency, non-phase critical applications, a slight disengagement of the interface will not adversely affect the electrical performance, when external forces pull on them. However, as the frequency increases, the instability of bayonet designs can be a major concern. This problem has been addressed with higher performance bayonet designs such as the TMA that combine precision interfaces with higher force coupling mechanisms.

MULTIPORT CONNECTIONS

Connections utilizing multiple contacts can be used to make reliable connections over a wide range of frequencies. The advantage of these connection systems is that the individual contacts are spring loaded and installed into an overall connector that is not torque sensitive. As with threaded and bayonet mount connectors, it is important that the RF plane of the two mating contacts remain securely engaged under all conditions.

Multiport connectors are available in a wide range of sizes and styles. These include styles from the very small contacts that fit the size 12 and size 8 cavities of MIL-C-38999 connectors, M8 connectors that have equivalent performance to precision TNC, to size 1 contacts for ARINC connectors that have the same interface as type C and SC connectors. An example of an M8 multiport connector installed on an aircraft is shown in ***Figure 4***. ■



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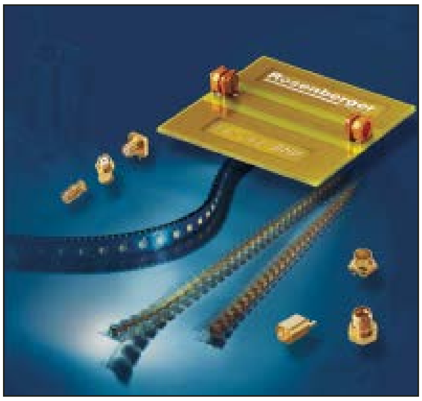
A FLEXIBLE MICROSTRIP CONNECTOR

The demand for additional integration and high density packaging in circuits for telecommunications, aviation and military applications continues to increase. The result is that components assembled on PCBs and into packages must be reduced in size and made suitable for new assembly techniques such as surface-mount technology (SMT). However, classic coaxial connectors and their mating interfaces have reached their limitations in some applications and have become a critical factor in high signal speed and broadband applications.

Faced with an evolving market with challenging demands Rosenberger took a close look at existing state-of-the-art coaxial connectors, considered their limitations and put forward possible solutions for high speed signal transmission in board-to-board applications, multi-chip mode (MCM) packages and on-board interconnection techniques. The objective being to develop an innovative interconnection system for high frequency board-to-board connections and the result is the Flexible Microstrip Connector (FMC) series.

Fig. 1 SMP connectors.

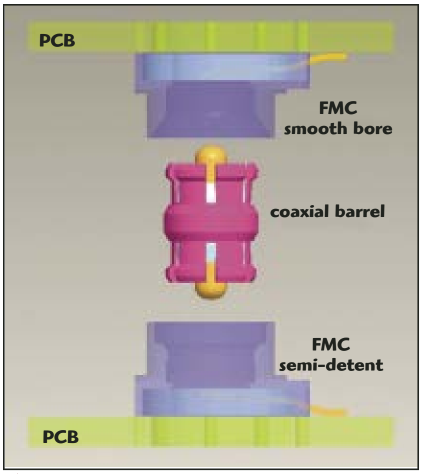


ESTABLISHED CONNECTORS

Over the past 10 to 15 years coaxial connectors have been developed for use in board-to-board applications with frequencies of 50 GHz or higher, the most prominent being the SMP (shown in ***Figure 1***) and Mini SMP connectors. They provide good overall frequency characteristics together with the ability for high density packaging. Since these connector interfaces are pin/socket configurations, strict rules for tolerances are required to avoid destructive mating.

The most limiting design factor for these small connectors, however, is the center contact. The nominal center contact diameters for the SMP and Mini SMP connectors are 0.85 mm and 0.75 mm, respectively. Now factor in a mating-pin diameter of 0.40 mm for SMP and 0.32 mm for Mini SMP and the potential for contact finger deflection and destructive mating is high, especially if tight positioning tolerances are not maintained. Furthermore, tight tolerances in piece part manufacturing and in PCB-board layouts can have significant cost implications.

ROSENBERGER
HOCHFREQUENZTECHNIK
Tittmoning, Germany



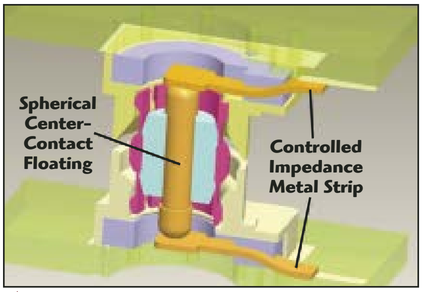
▲ *Fig. 2 A standard PCB application with Flexible Microstrip Connectors.*

AXIAL TOLERANCE

Another consideration that the Rosenberger development engineers had to consider is the limited axial direction tolerance in board-to-board coaxial connectors. The standard configuration is a PCB-mount connector on both boards, which are connected via a coaxial bullet to equalize the displacement in the axial direction. Some designs accommodate for this displacement with a spring-loaded, floating coaxial connector on one of the PCBs but this can be expensive and requires additional geography on the PCB making it less desirable for high density packages.

The SMP and Mini SMP offer a simple and cost-effective solution to this problem. The principle is, that on one side there is a smooth bore PCB connector and on the adjacent board, a full detent or semi-detent style connector is mounted. This allows the coaxial bullet to accommodate the axial tolerances in the board-to-board configuration. However, the disadvantage is the change of impedance in the interface from the bullet to the PCB connector depending on the (distance) tolerances between the boards. With the SMP interface, the step in impedance due to axial displacement is a change from an almost 50 Ω characteristic impedance to 100 Ω. At higher frequencies this has a significant impact on the repeatability of the interconnection.

The next area that had to be addressed was the angular and radial displacement of the boards. In this situation, a high mechanical stress is loaded on the contact fingers of the socket center contact. Since there is only a maximum 0.20 mm wall thickness of these contact fingers too much radial and angular deflection may destroy the socket contact or bend the mating pin such that the characteristics of the connection can no longer be guaranteed.



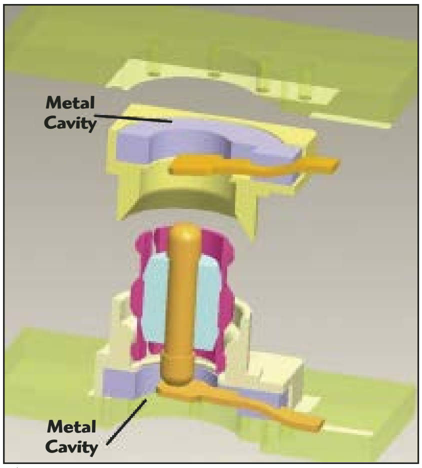
▲ *Fig. 3 The spring-loaded metal strip connecting to the board's stripline in an impedance-controlled manner in the fully assembled position.*

Another consideration is that special care has to be taken at the connection of the PCB connector to the board. At this interface is a transition from the coaxial TEM mode of propagation into the mode of propagation of the individual planar transmission line structure. To reach the optimum transmission characteristics, a footprint has to be developed, especially for higher frequency ranges. Rosenberger therefore developed special connectors for PCB and planar structures to support high frequency applications whereby the transition from coaxial line structure to the planar structure is made inside the coaxial connector. Thus, the rear interface is a planar structure almost mirror imaging the footprint on the board, which provides a very reliable impedance controlled and repeatable transition from the coaxial connector to the PCB.

This technique is able to support every available assembly process, such as surface mount, pin in paste, etc. Also, the footprints take into consideration all of the parameters in relation to board materials, board thickness, transmission line structure and plating materials.

A NEW CONCEPT

By analyzing all these parameters and the traditionally available options, Rosenberger has been able to develop a totally new concept in coaxial board-to-board connectors — the Flexible Microstrip Connector series. The basic idea behind this series was to avoid an expensive slotted contact with all its mechanical and electrical restrictions. Other significant design criteria included ensuring that the angular and radial displacement should not be limited by the center contact only and that a floating element must be used to compensate for the axial displacement.



▲ *Fig. 4 The spring-loaded metal strip connecting to the board's stripline in an impedance-controlled manner in the half-assembled position.*

Other major considerations were that the transition from planar to coaxial should be carried out in an impedance controlled environment and that the connectors' mating surface should mechanically and electrically match the standard footprints of existing connector series, such as SMP, Mini SMP and others on the market.

The FMC in general follows the principle of the SMP board-to-board connectors. On one side there is a smooth bore outer contact to allow the axial displacement. On the adjacent board is a semi-detent outer contact designed to keep the coaxial bullet in place. The configuration is shown in ***Figure 2***. The pin and socket center contact that is incorporated in traditional designs has also been eliminated. Here, the center contact of the PCB connector is a spring-loaded metal strip, which connects to the board's stripline in an impedance-controlled manner, as shown in ***Figure 3***.

The other end of this metal strip connects to the ball-shaped end of a 'barrel's' center contact. This end of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the metal strip incorporates a surface dimple to enable a multi-contact point, low resistance transition. As the spherical end of the center contact is ball-shaped it means that the barrel can accept displacement in angular and radial directions without damaging a pin or a contact finger.

In the axial direction, the longitudinal tolerances are equalized by the movement of the metal strip inside the board connector, while the center contact has some limited float relative to the dielectric isolation and support (see ***Figure 4***). The net effect is that both sides of the barrel are constantly positioned with an equal force created by the pressure exerted from the spring-loaded metal striplines.

REPEATABILITY

For improved impedance matching, the flexible metal strip is positioned inside a cylindrical metal outer contact. The electrical structure is a quasi-coplanar line and the electromagnetic fields are distributed between the metal strip and the ground surfaces of the cylindrical bore of the outer contact. This feature guarantees high repeatability, since there is no variation in the geometry of the center contacts and the metal strip's mating plane.

The contact area is similar to the existing SMP structure and, with a properly designed footprint, will provide an optimum frequency response up to 20 GHz. The Flexible Microstrip Connector is designed for frequencies of up to 10 GHz, but still has good performance up to 20 GHz, while connectors featuring the FMC principle for higher frequencies are in development.

The technological development of the FMC is not only practical but the innovative design of the center contact mating structure also has a significant, positive impact on the manufacturing cost of the connectors. In particular, the flexible microstrip of the board connector is produced with a one step precision molding and stamping process, and the spherical ends on the barrel's center contact are manufactured via a micro-forming process. Both of these processes guarantee a high level of precision and low manufacturing costs in high volume production.

CONCLUSION

The Rosenberger Flexible Microstrip Connector matches the very good performance of pin and socket type connectors, such as the SMP and Mini SMP, while also offering a cost-effective solution that eliminates some of the mechanical and electrical restrictions of other types of board-to-board coaxial connectors. The FMC easily matches the performance of other connectors up to 10 GHz frequency at a significant reduction in manufacturing and application costs.

Rosenberger Hochfrequenztechnik, Tittmoning, Germany, +49 (0) 868 4180, info@rosenberger.de, www.rosenberger.de.

RS No. 301

BRAZE-FREE TYPE N RIGHT ANGLE CONNECTORS

San-tron Inc. introduces a new series of braze-free, 50 Ω right angle connectors that feature silver-plated center contacts and bodies, and an Albaloy-plated coupling nut. They are designed in accordance with MIL-STD-348 interface and the design allows for the connectors to be used up to 11 GHz, while most other right angle connectors are limited to 9 GHz.

Utilizing Hydromat technology, San-tron has redefined the manufacturing process in the implementation of these right angle type N connectors by harnessing the high performance, low cost and adaptability of this technology. This approach results in:

- Lower operating costs
- Lower component costs
- Reduced lead-time
- Broad scope – commonality of components
- Highly reproducible RF performance
- Indestructible mechanical performance

Figure 1 illustrates how this technique is adaptable to many applications. The base module encompasses the type N interface, the coupling mechanism, the right angle structure and the launch. With the base module used as the foundation of a product line, a host of possibilities for different applications opens up. Through the deployment of secondary modules, as illustrated, the following right angle topologies can be implemented:

- Clamp-style cable
- Crimp-style cable
- EZ-style cable
- Between series adapters
- Black box portals

The heart of this methodology is the type N interface base module that incorporates the right angle and launch zones. Machined from solid 1.00-inch bar stock on a 16-head Hydromat, the RF structure, from reference plane through the right angle and into the subsequent launch, is controlled by primary machining processes. Therefore, there are no secondary operations that can shift the centerline development of the RF structure. Every assembly is identical in phase length, impedance structure and registration of the dielectrics and center contact — a direct outcome of the investment in Hydromat technology.

SAN-TRON INC.
Ipswich, MA


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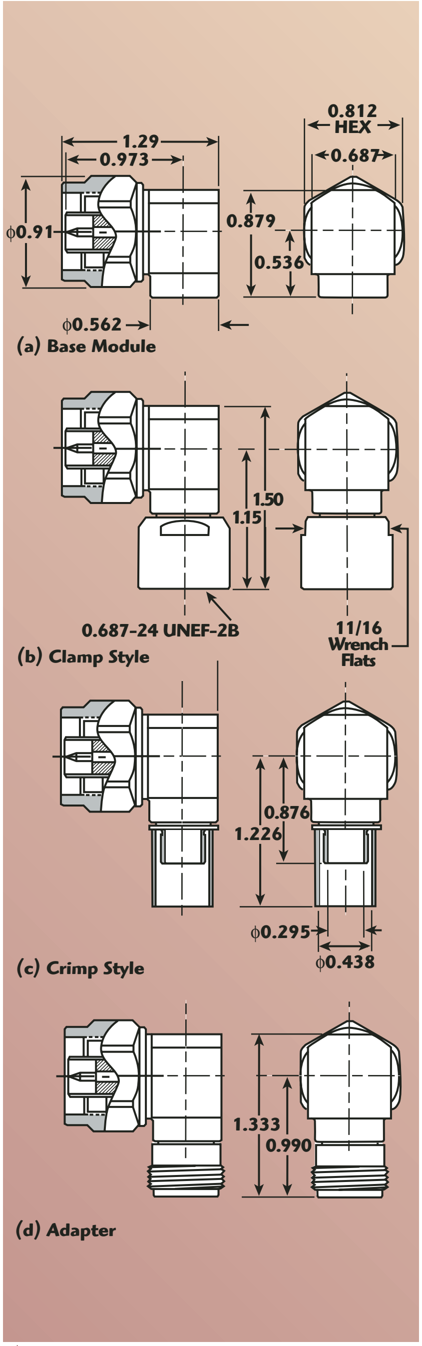
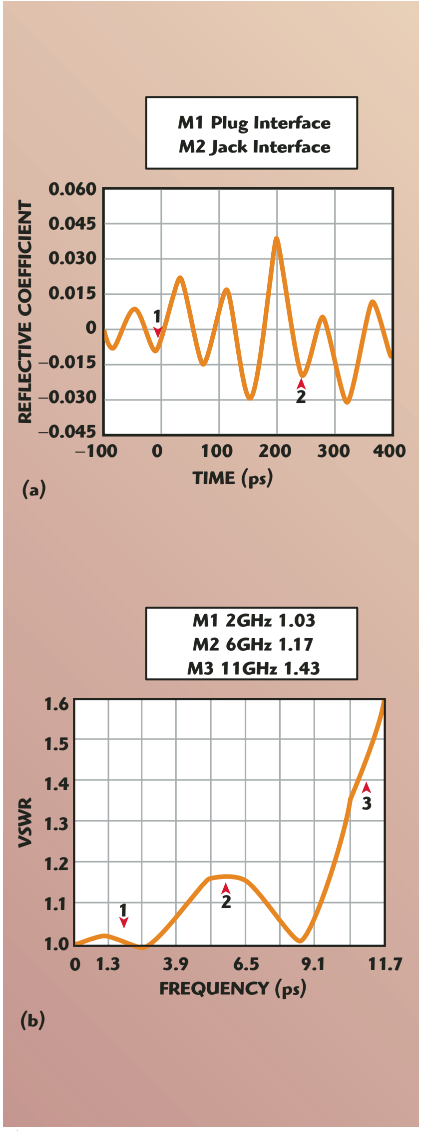


▲ *Fig. 1 Hydromat technology is adaptable to many applications.*

▲ *Fig. 2 Right angle Type N adapter.*



▲ *Fig. 3 Measured performance of a right angle adapter; (a) time domain reflection coefficient and (b) VSWR.*

The tooling budget to outfit a Hydromat is a customized deployment that does not support flexible manufacturing. The technique also requires a 40-hour setup and cannot be deployed with an expectation of inventory turns at the component level. When this process is turned on, however, a huge amount of product can be run and important economies of scale can be realized. Therefore, although the economic disadvantage appears obvious (the need to carry a six-month inventory is against every principle of modern management operations), an upside is apparent when the total logistic stream is reviewed. This one complex component supports a wide variety of products with a simplified routing structure.

CLAMP-STYLE RIGHT ANGLE CONNECTOR

First implemented as a clamp-style right angle connector, this was a very simple bill-of-material (BOM), thus establishing the most basic logistic stream. Using standard cable termination hardware that has been offered by San-tron for over 50 years, the commonality of components ensured a low cost, high turn inventory structure. A single new component was required to complete this design: a physically short, easy-to-machine body that could be dropped complete from low cost Brown & Sharp operations. This technique resulted in an assembly comprised of one complex, low turn component and a BOM of low cost, high turn inventory, fulfilling the need for lean manufacturing deployment.

RIGHT ANGLE TYPE N ADAPTER

The second implementation is a right angle type N adapter, shown in ***Figure 2***, the development of which makes use of three unique technologies. The first one is the implementation of the dual displacement press fit. The primary press fit is composed of opposing smooth bore cylinders that result in an IP-66 junction. The secondary press fit is a traditional straight knurl that enhances mechanical captivation. This dual displacement press fit establishes a mechanical junction that is stronger than either of the individual methods. Under destructive torque-to-failure testing, the connector bodies are grossly deformed without rupture of the press fit junction. The second technology introduces an optical wave shaping through the right angle connector. Employing optic principles, the dielectric and center contact are developed such that the TEM field is pre-shaped and intensified through the interior elliptic surface. As shown in ***Figure 3***, this technique establishes a reflection coefficient (ρ) through the right angle structure that is limited to ρ = +0.015 (51.5 Ω), and then recovers to ρ = –0.030 (47.1 Ω). Notice also the inductive characteristics of the two interfaces. Due to the geometric plan of the type N plug, the typical inductive spike of the type N interface is virtually eliminated to a level of ρ = +0.022 (52.2 Ω). The type N jack interface is more traditional

and results in ρ = +0.039 (54.1 Ω). As an added benefit, the dielectric geometries are such that miter joints and secondary operations were again eliminated from the design, thus further reducing sources of error and cost. The third technology is the development of solder-free compliant pin contacts. The center contact is a two-piece construction comprised of a cross-drilled tab contact machined of brass and a slotted compliant pin machined of BeCu. These two components are interlocked and establish an irreversible connection. The resultant contact exhibits a highly reproducible RF structure devoid of operator skill and process variations. This development of the right angle cable plug and the right angle adapter establishes the basis for new products offering advanced technological enhancements. The omission of brazing and soldering operations establishes a seamless technology that is easily implemented throughout San-tron's worldwide organization. The process is highly constrained and reproducible. The omission of brazing and soldering not only eliminates the variations associated with reduction atmospheric ovens and soldering process, but also supports the lean manufacturing goals of reducing lead-times, eliminating the use of special processes, and reducing the criticality of employee training and certification. Whether these assemblies are to be manufactured in the Caribbean, Suzhou, China, or at San-tron headquarters in Ipswich, MA, the resultant connectors exhibit advanced performance characteristics at a commercial pricing structure.

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HIGH DENSITY INTERCONNECT SOLUTIONS

The need for a compact and reliable high frequency interconnect system has spawned a new family of connectors for microwave and high speed digital applications. Southwest Microwave's family of SSB coaxial connectors features an extremely small pitch with superior high frequency performance. The family is comprised of the SSBP push-on, the SSBT threaded and the SSBB bulleted ultra-miniature connectors. Unique applications for SSBP contacts include use within industry-standard D38999, D-Subminiature, Micro-D and other multi-contact connectors.

The SSB connector family is designed around a common interface with air dielectric and a center conductor captured with high temperature plastic beads. SSB connectors utilize the same materials and construction that Southwest Microwave has used for many years in their other air dielectric connectors.

▼ *Fig. 1 The SSB interface.*

The air dielectric instead of PTFE provides a lower loss transmission path and allows for greater phase stability in misalignments, vibration and temperature variations.

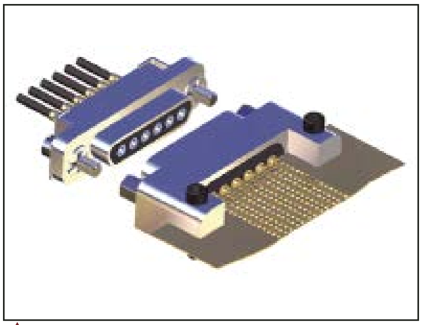
Superior microwave performance is obtained by using transmission line principles throughout the interconnect system. This includes compensated transitions, high quality plating and proprietary innovations.

The interface shown in ***Figure 1*** displays both the pin (plug) and socket (jack) interfaces. On the left is the pin (plug) end and on the right is the socket (jack) end. On the cable termination ends of SSBP contacts, there are inspection holes so the cable center conductor can be inserted properly. The geometry is based on 0.9 mm connector standards.

SSBP

The SSBP version is a push-on contact designed to be used in industry standard multi-contact connectors or can be arrayed in a custom envelope for maximum flexibility. The SSBP interface engagement starts with a low insertion force mate. The spring-loaded sleeve is then compressed when the multi-contact connector is fully engaged.

SOUTHWEST MICROWAVE INC.
Tempe, AZ



▲ *Fig. 2 A typical multi-pin application.*

The SSBP interface sides are designated as pin and socket following the convention of the multi-contact connector industry. Standard insertion and extraction tools will work with SSBP contacts. The interfaces are terminated for cable or end launch and compatible with 0.047, 0.086 and other cable types. Multiple contact sizes currently available include 20 and 16, with size 12 in process. Versions are available for industry standard MIL-DTL-38999 (Series I, III and IV), D-Subminiature (MIL-PRF-24308) and Micro-D connectors (special contact arrangements in MIL-PRF-83513 housings). ***Figure 2*** shows a typical multi-pin application in a Micro-D envelope.

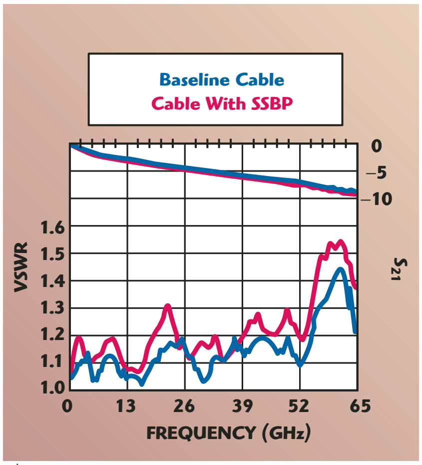
▲ *Fig. 3 An SSBT configuration.*

SSBT

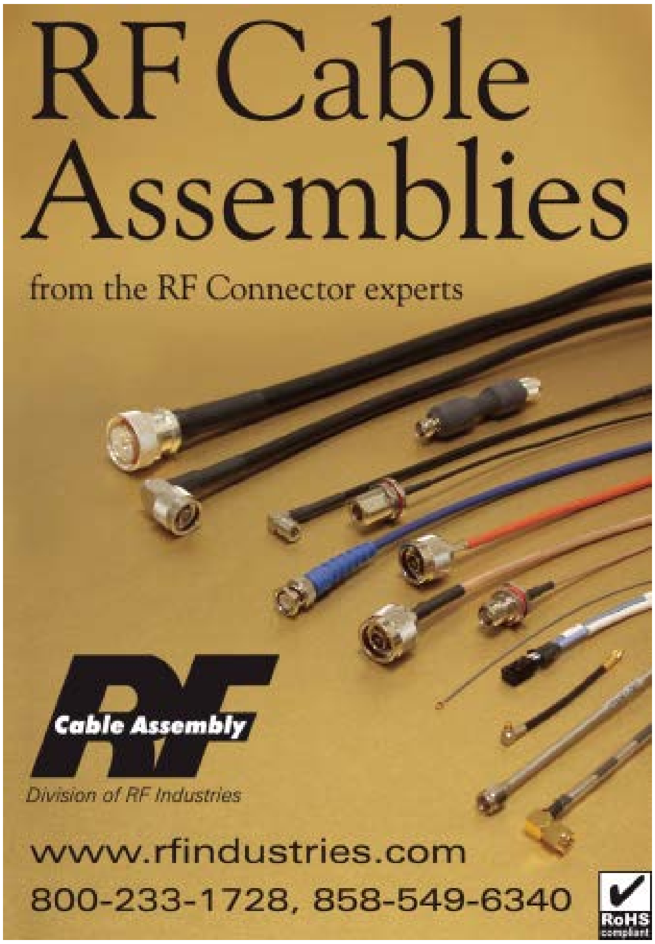
The SSBT is the threaded version of the SSB family. It is designed as a replacement to traditional microwave connectors where there are small size or high frequency requirements. The SSBT is available in field replaceable, cabled or adapter configuration.

The SSBT thread is a 2-64 with an outer housing diameter of 0.100 inch. The standard coupling nut has a 0.125" hex. The minimum spacing is 0.250" connector-to-connector (see ***Figure 3***).

▲ *Fig. 4 SSBB interface components.*



▲ *Fig. 5 Typical electrical performance to 65 GHz.*



SSBB

The SSBB is the bulleted version for board-to-board or module-to-module stacking applications. The bullet allows for misalignment of connectors while maintaining a good microwave connection. The SSBB has a bullet diameter of 0.060" and is available in several lengths. The smallest length is 0.110" and allows a ±0.012 (total 0.024") axial misalignment. Longer bullets will allow more misalignment. ***Figure 4*** shows a sample of SSBB components. Minimum board-to-board spacing is 0.170" with 0.080" centers.

PERFORMANCE

To electrically evaluate the SSB interface, a pair of SSBP contacts was inserted into a reference two-foot long 0.047 flexible cable assembly with 1.85 mm plug connectors and tested to 65 GHz. The SSBP contacts were installed in D38999 circular connectors for testing. ***Figure 5*** shows baseline cable assembly results (blue line) and then the same cable with the SSBP contact pair included (red line). The difference is the contribution of the SSBP pair.

Applications for the SSB interface include board-to-board and module-to-module connections, multi-contact connector interfaces, multi-line testing uses and blind-mate configurations. The SSB interfaces are ideal for airframe cabling, test equipment, transceivers, avionics and cabling arrays where high packaging densities and high frequency performance are required.

Southwest Microwave Inc.
Tempe, AZ (480) 783-0201,
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RS No. 306

QUICK CONNECT SMA CONNECTORS

Winchester Electronics is announcing the addition of the newly released QC-SMA™ series of RF connectors to its standard product line. The QC-SMA series incorporates a push/pull style of mating that does not require torque wrenches or any other tool for mating or unmating. This revolutionary new series is also backwards compatible to existing jack connectors in the field. Typical applications for this connector could be in PCB test boards, microwave subsystems, base stations, test equipment, mobile radios and anywhere a quick connection is required.

These new connectors offer several benefits:

- The push/pull connection system allows quicker mating
- When mated, the connectors can be rotated 360°
- Their electrical performance is comparable to standard SMAs, up to 6 GHz
- Their compact design utilizes the SMA standard spacing down to 0.5 inch center to center
- Designs are available for both flexible and semi-rigid types of cable

Fig. 1 Mating sequence for the QC-SMA connector.

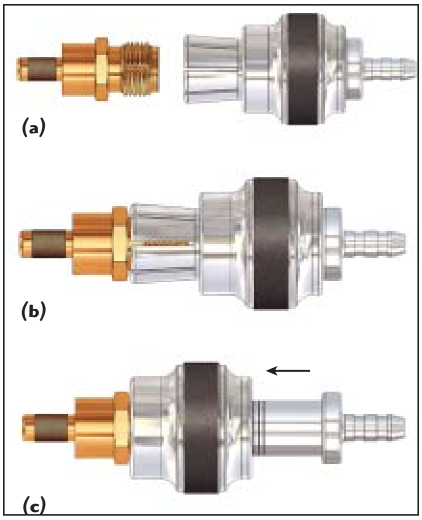

Figure 1 shows the sequence of the mating operations. First, in the open, unmated state, the shroud is pulled back. The QC connector is then pushed into its mate while holding onto the shroud. The mating is completed by pushing the shroud forward. ***Table 1*** shows the electrical characteristics of the QC-SMA connectors.

The body and outer contact are made of a copper alloy while the body components and male contacts are made of brass per ASTM B16. The insulators use PTFE (Teflon) per ASTM D1710. The crimp ferrules are made of copper alloy. The center contacts are gold plated (ASTM B4888) over a nickel plate (QQ-N-290). The other metal parts are gold, nickel or tri-metal plated to meet the corrosion requirements of MIL-PRF-39012. The mating or unmating force is 10 lbs maximum while the fully mated connector retention force is 30 lbs minimum. The durability of the connector exceeds 500 cycles. The temperature rating of the QC-SMA connector is – 65° to +165°C.

TABLE I

ELECTRICAL CHARACTERISTICS OF THE QC-SMA CONNECTOR

Nominal impedance	50 Ω
Operating frequency	DC to 6 GHz
VSWR	1.25 max
Insertion loss (dB max) Straight Right angle	 $0.4 \times \sqrt{f}$ (GHz) $0.7 \times \sqrt{f}$ (GHz)
Insulation resistance (MΩ)	5000
RF leakage (dB) @ 2 to 3 GHz	–60

Winchester Electronics, Wallingford, CT (203) 741-5400, www.winchesterelectronics.com.

RS No. 305

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6	M/A-COM, Inc.	33	800-366-2266	978-442-5350	http://mwj.ims.ca/8586-6
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8	Micro-Coax Components	27	800-223-2629	610-495-6656	http://mwj.ims.ca/8586-8
	Microwave Journal	16,17,42	800-225-9977	781-769-5037	www.mwjournal.com
9,10	Mini-Circuits	19,22-23	718-934-4500	718-332-4661	http://mwj.ims.ca/8586-9
11	Radiall	5	33-1-49-353535	33-1-48-546363	http://mwj.ims.ca/8586-11
12	RF Cable Assembly, Division of RF Industries	38	800-233-1728	858-549-6340	http://mwj.ims.ca/8586-12
13	RF TEC Mfg., Inc.	42	770-487-2187	770-486-9499	http://mwj.ims.ca/8586-13
14	Richardson Electronics, Ltd.	31	800-737-6937	630-208-2550	http://mwj.ims.ca/8586-14
15	Rosenberger	28	+49-8684-18-0	+49-8684-18-499	http://mwj.ims.ca/8586-15
16	Spectrum Elektrotechnik GmbH	21	+49-89-3548-040	+49-89-3548-0490	http://mwj.ims.ca/8586-16
17	Storm Products Company	37	630-754-3300	630-754-3500	http://mwj.ims.ca/8586-17
18	SV Microwave, Inc.	3	561-840-1800	561-842-6277	http://mwj.ims.ca/8586-18
19	Tensolite	COV 3	800-458-9960	904-829-3447	http://mwj.ims.ca/8586-19
20	Thermax/CDT	4	888-761-7800	718-746-4190	http://mwj.ims.ca/8586-20
21	Times Microwave Systems	39	203-949-8400	203-949-8423	http://mwj.ims.ca/8586-21
22	TRU Corporation	25	800-262-9878	978-531-6993	http://mwj.ims.ca/8586-22
23	W.L. Gore & Associates, Inc.	34	800-445-GORE		http://mwj.ims.ca/8586-23
24	Winchester Electronics	41	203-741-5400	203-741-5500	http://mwj.ims.ca/8586-24