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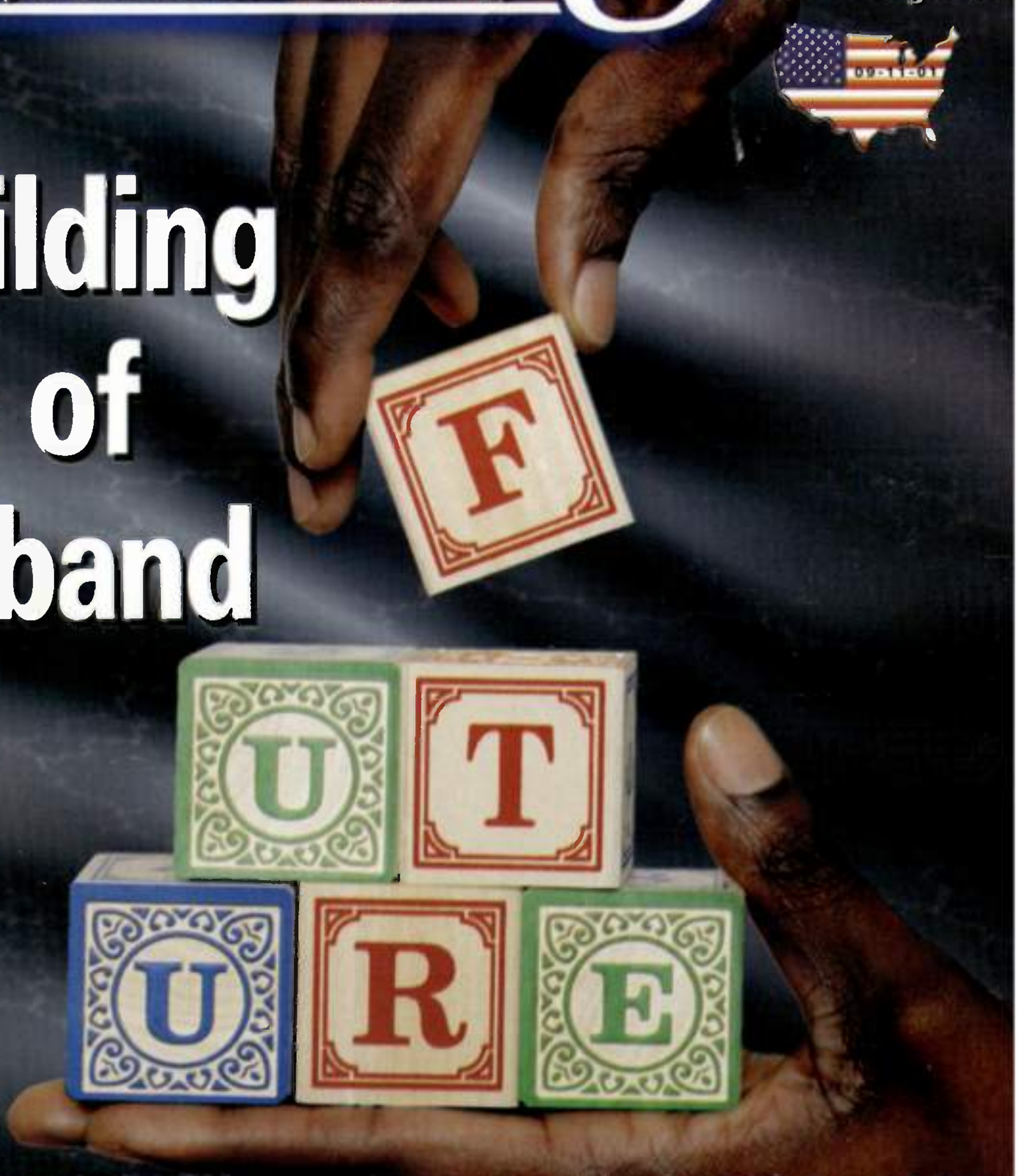

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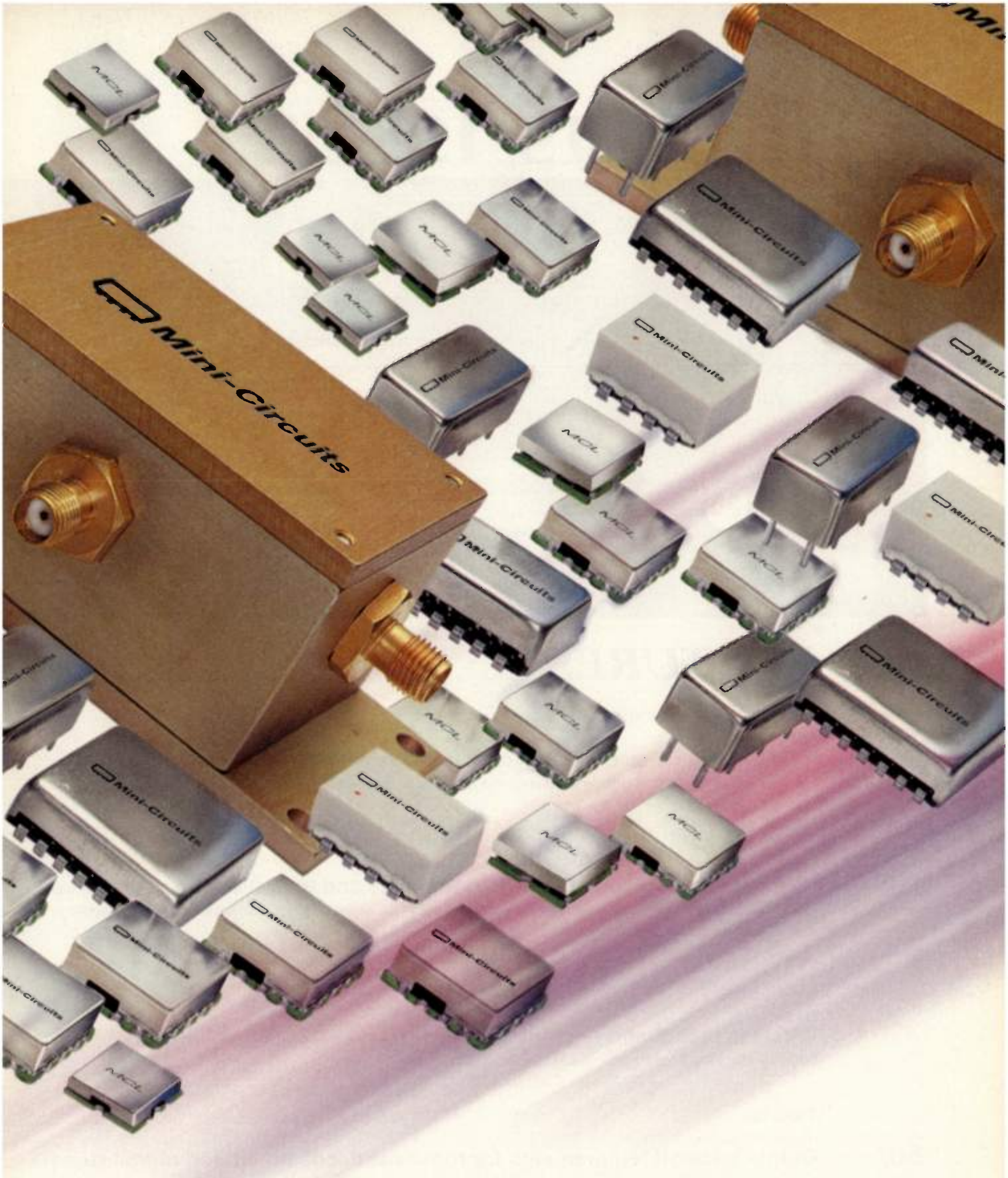
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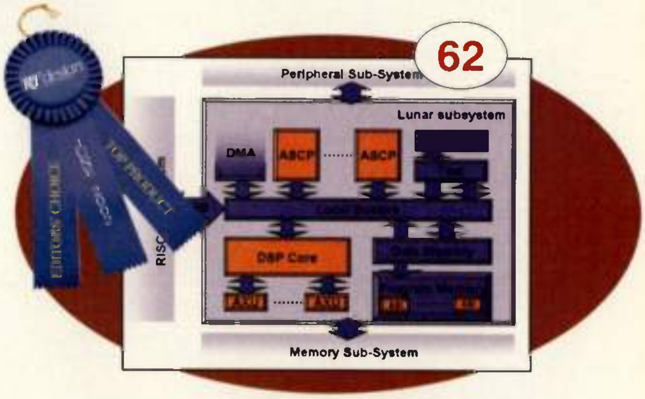

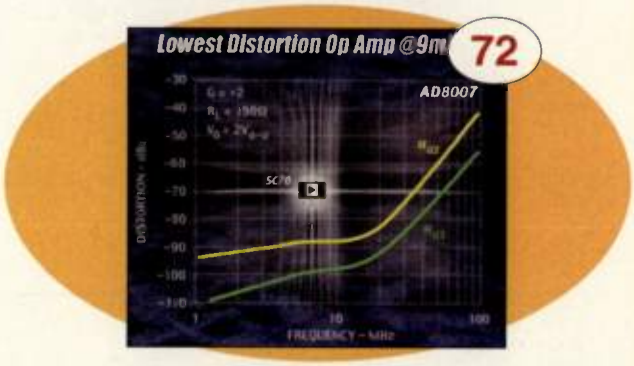

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RF editorial

OEMs: Do it yourself — not

By Don Bishop
editorial director
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Design and development engineers, otherwise known as *RF Design* readers, more commonly work for original equipment manufacturers than their labor suppliers, the electronic manufacturing service companies. Yet the proportion may shift more in favor of EMS companies.

OEMs traditionally pride themselves on their ability to design and manufacture products to military and industrial specifications and to meet consumer desires, as the case may be. In doing so, they take on a large measure of risk. The most recent example of that risk was the effect on OEMs caused by inventories that became "excessive" with last year's dramatic reduction in product demand.

For example, Santa Barbara, CA-based iSupply, a company that helps suppliers to monitor their buyers' inventories, estimated that some companies shipped as much as 18 months' worth of product in 2000. Some OEM employees later paid for the disjointed sales with their jobs in 2001.

"Lucent is half the size it was 24 months ago," said Lloyd Kaplan, vice president of iSupply. He spoke to an audience in April at a meeting of the Electronic Components, Assemblies and Materials Association.

As OEMs seek to wring more risk from their operations through continually reducing costs, the increasing use of EMS companies to outsource their manufacturing follows. Moreover, some want EMS companies to shoulder some of the inventory burden and research and development risks.

Where OEMs and EMS companies already have close relationships and good communication, the results tell the story.

Kansas City, MO-based Midland Radio cut its engineering cost to 5% to 10% of what had been the norm when it shifted engineering for certain products to an Eastern European affiliate.

West Melbourne, FL-based Relm Wireless revitalized part of its product line by using engineering and manufacturing service from Shenzhen HYT Science and Technology, Shenzhen, China. Relm previously swapped buildings, equipment and employees with an EMS division then owned by Honeywell to bring its risks and costs into better balance for other parts of its product line.

Defining customer demand remains top-line for OEMs. Once in a while, though, when engineers are left unsupervised (Have mercy!), they might come up with products that market research never requested but that newfound end-users can't live without. That's part of the magic of invention.

Meanwhile, a combination of accurate inventory accounting, reasoned forecasting and honest sharing of numbers would help OEMs to avoid replicating the breathtaking shortfall in RF-related product sales of the recent experience. What the OEMs don't want to do for themselves, some EMS companies are ready to supply, including engineering talent.

Without conducting their own market research, EMS companies will remain what they are, meaning they won't turn themselves into OEMs. That possibility exists, though, and the first evidence of it might be found in Asian markets. Yet, the more responsibility the EMS companies assume, the more they risk raising their costs and losing their appeal to OEMs as a low-cost manufacturing service provider.

Even so, design and development engineers may find potential for growth in the EMS segment that shouldn't be overlooked.

Whether an OEM should have engineering done in-house or under contract with an EMS company has implications for their marketing and cost control, not to mention the career planning for design and development engineers.

Don

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INFO/CARD 3

The false growth of broadband

By Roger Lesser
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While we await the resurgence in telecom (and the trickle-down effect it will have on the industry), the last thing we need to hear is that broadband growth is a hoax. Yet, that is exactly what appears to have happened.

An article that appeared in the 17 May issue of *The New York Times*, indicts energy companies for creating a false image of a growth market for broadband over the last couple of years.

According to the article, a number of energy companies, including Enron, engaged in "round-trip trades." This was accomplished by the energy companies selling "routes" to one another at the same price on the same day. One company, Reliant, made more than 50 such "trades" a day from April to October of 2001.

The whole idea behind the scheme, the article notes, was to give the perception of a fast-growing communications market and to attract telecom companies to do business. Enron predicted it would make $17 billion from the broadband market by 2005, according to a February 2000 report by J.P Morgan.

Now the Securities and Exchange Commission (SEC) and the FBI are investigating. Needless to say, the energy companies deny they would do such a thing and will not comment. But when the SEC and FBI come knocking, it's like you or me hearing the door bell ring and opening the door to see Mike Wallace. It isn't going to be a good thing. And, given what we have seen from Enron and Global Crossing, there is good reason to investigate.

The savior needs saving

Many analysts saw broadband growth as the white knight sent to slay the dragon of the telecom downturn. Now the knight needs saving. The investigation will most likely be long and drawn out. But, I believe, if Enron's other debacles are any indication, the energy companies are going to be found guilty as charged. The question then becomes, what next? What needs to be done to bring an active and viable broadband to life?

The savior of the savior may be the technology itself. Like any technology, it takes time to grow and mature. Forcing it, as the energy companies appeared to try, only leads to problems. One need only look at Microsoft Windows and the joy it has brought users. As the software matured (and patches applied), Windows became the defacto operating system. Also, the consumer must be the drivers behind the growth. Once they see broadband applications as a must-have technology, like the microwave (How did we ever live without the microwave?), the technology and market will grow and prosper.

Roger

In-Stat/MDR optimistic for semiconductor industry

In a presentation delivered May 1 at the Embedded Processor Forum in San Jose, In-Stat/MDR announced its newest semiconductor industry forecast. Chris Van Gaal, senior director of content development, reported that, as predicted, 2002 will continue to be a corrective year for the industry. 2002 worldwide semiconductor sales are forecast to decline an additional 4-5% from 2001 despite sequential quarterly growth. However, in 2003, an optimal combination of inventory depletion, order rates and market dynamics will result in a 30.7 % increase in worldwide semiconductor sales over the year prior.

According to Van Gaal, many indicators signify a marked turnaround in an industry that experienced a 32% decrease in sales last year. A rise in both regional and global gross domestic product (GDPs) and order rates in key end-use segments are an indication of a brighter future, he said, as they are closely tied to the semiconductor industry. Van Gaal cited an average two-year lag time between capital investment and full-fledged fab output and swings in revenue growth resulting from the difficulties in maintaining a good balance between supply and demand as continuing influences on the market's volatility.

Quest for speedier access to aid broadband penetration

Growing demand for high-speed Internet services, triggered by exponential demand for bandwidth and the increasing volume of traffic, is driving the need for broadband access, according to Frost & Sullivan's, London, latest report. The research firm believes that the number of Western European broadband subscribers will rise from 3.8 million broadband subscribers in Western Europe at the end of 2001 to hit the predicted subscriber mark of 28.1 million in 2008.

As the telecom industry is gearing up for a rebound and the economic climate stabilizes, 2003 will be the European broadband market's watershed year, Frost & Sullivan said, when the number of subscribers will start to grow immensely.

Rising demand for increased connection speeds is a key factor providing impetus for rapidly increasing broadband penetration. Demographic changes, including the growing office/home office (SoHo) population, will further contribute to the acceleration of broadband communications adoption.

BUSINESS BRIEFS

WTT receives order from the U.S. Navy — Wireless Telecom Group, Paramus, New Jersey, announces that its wholly owned subsidiary, Boonton Electronics, has received an order from the U.S. Navy for its 1121 Audio Analyzers. These orders are for about $500,000 and are scheduled to ship in the second quarter of 2002.

Chinese IC design center partners with Credence — Credence Systems, Fremont, CA, announces a partnership with the Chinese government-sponsored Nation I.C. Design Industrial Base (NICD IB) in Beijing, China. NICD IB, with the help of Credence, will provide technology resources to more than 65 local design houses and 10 major universities. Under the partnership, Credence will provide NICD IB with testing technology with the installation of a Quartet system-on-chip (SoC) production test system.

HOT WEB SITE

WLANA: Clearing up the WLAN alphabet soup

Do all of the 802.11 standards have you dizzy? Are you even more confused about who all of the different WLAN organizations are and what they do? The Wireless Local Area Network Association (WLANA) has compiled a guide to help you weed through the alphabet soup. A brief guide to wireless networking standards and the organizations involved in defining and/or promoting those standards can be found on the WLANA web site. Go to the online Learning Center and click on "WLAN Standards and Organizations" to download the PDF.

WLANA
http://wlana.org/learning_center.html

How to build EM-accurate, parameterized passive models

Getting the product out the door right the first time is paramount to the bottom line. Modern EM parametric modeling tools can help make it happen.

By Mounir Adada

To meet time-to-market goals, the designers of high-frequency wireless and wireline devices rely on electronic design automation (EDA) software. Computer simulation of circuits and systems is an essential part of the development process, and accurate component and circuit models are required

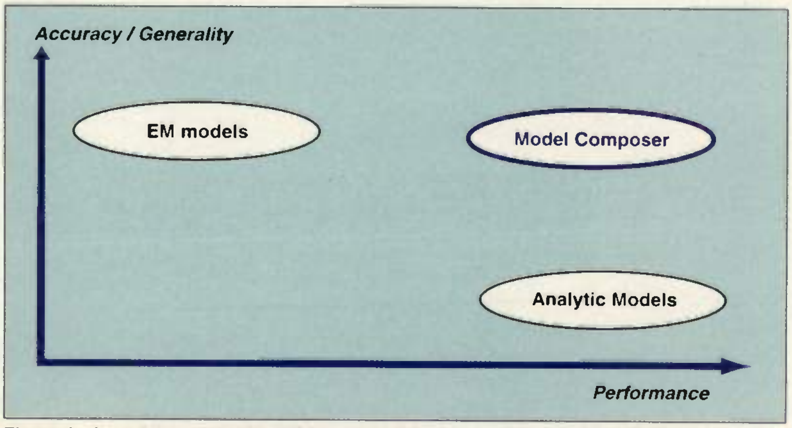

Figure 1. A model composer's EM-based modeling accuracy against performance.

to ensure that the simulations reliably predict real-world performance. As frequencies of operation and circuit complexity increase, the accuracy of these models must keep pace. Recent developments in modeling technology now empower designers to define the accuracy of their high-frequency passive models. Designers no longer have to settle for predefined generalized models that only work for limited frequency ranges and process properties.

Using new technology, engineers can automatically generate key passive models using the frequency range, material properties, number of parameters and desired accuracy. Linear simulators enable generation of electromagnetic (EM) accurate parameterized passive models with the simulation speed of analytical models. With this technology designers are no longer restricted by the limitations of older modeling methods.

Accurate models enable fast simulations

The fastest simulations are obtained with linear circuit analysis EDA tools. These tools rely on accurate analytical (mathematical) models to provide trustworthy results. With wireless and wireline designs constantly increasing in complexity and operating at higher frequencies, design engineers may exceed the limits of their EDA tool's passive analytical models. When these passive models are used outside their intended operational range, the EDA tool may return inaccurate simulation results.

The inconsistencies of legacy modeling techniques from the 1970s and 1980s hinder the accuracy of these models when they are applied to different processes and frequencies. Exceeding a model's frequency limit causes errors due to failure to account for higher-order propagation modes.

Limitations of the equivalent circuit model, such as frequency-independent inductive or capacitive elements, also lead to simulation errors. Because most EDA tools do not proactively report such errors, they may not be discovered during simulation — becoming apparent only when a prototype fails to perform as expected.

Many error-prone passive models tend to be of a discontinuous nature (i.e. microstrip or stripline cross, step, bend, open, gap, etc.) where multimode propagation is common. These structures can be fully characterized using full-wave EM simulation. These results can be applied to produce an accurate S-parameter model of the discontinuity, which can be used by the circuit simulator.

The challenges of modeling

Developing such new models is a complex task. To model a single parameter over a range of values, several sample points are required. Because the model can be a function of parameters such as line width, length, metal thickness, dielectric constant, substrate thickness and loss tangent, an exponential growth exists in the number of samples as the number of parameters increases.

Also, developing a new model usually requires a highly skilled person working for several weeks — or even months — to define, develop and test the desired analytical model. If the requirement is for a complete library of models, the total effort is multiplied by the number of models needed. The model development task needs to be weighed against

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VAT-4	HAT-4	4	4	0.15	0.08	1.15	1.1
VAT-5	HAT-5	5	5	0.10	0.06	1.15	1.1
VAT-6	HAT-6	6	6	0.10	0.02	1.15	1.1
VAT-7	HAT-7	7	7	0.10	0.05	1.15	1.1
VAT-8	HAT-8	8	8	0.10	0.04	1.20	1.1
VAT-9	HAT-9	9	9	0.10	0.02	1.15	1.1
VAT-10	HAT-10	10	10	0.20	0.03	1.20	1.1
VAT-12	HAT-12	12	12	0.10	0.05	1.20	1.1
VAT-15	HAT-15	15	15	0.30	0.05	1.40	1.1
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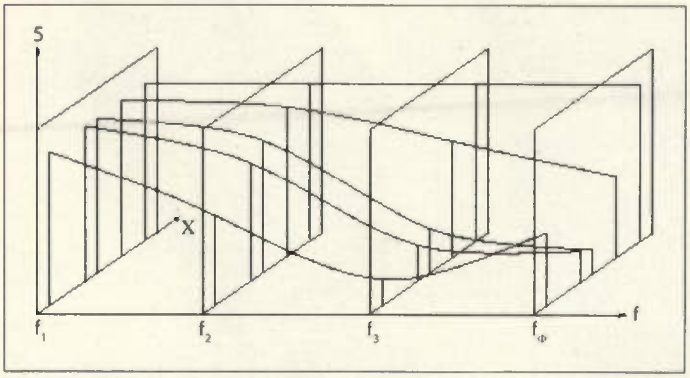

Figure 2. AFS rational models over the desired frequency range, derived from full-wave EM simulation.

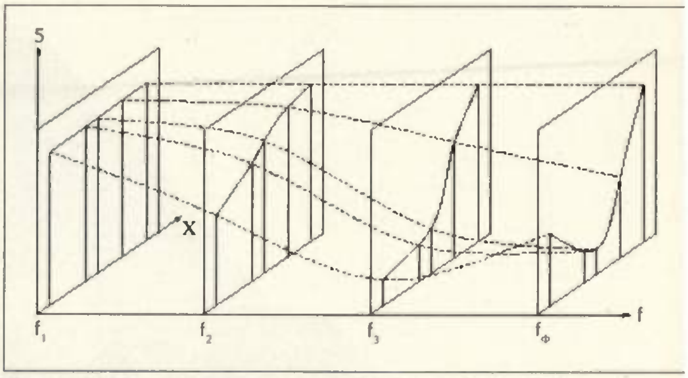

Figure 3. Multinomial models are created at discrete frequencies.

measurement-based or EM-based modeling on a case-by-case basis.

Some of the methods traditionally used for developing analytical models have limitations. Methods that use pre-calculations of equivalent circuits, including look-up tables, fitted equations and interpolation, can have a limited number of samples and insufficient interpolation methods.

An example that presents problems for these techniques is high-Q resonant circuits, such as those used in narrow band filters. Applying discrete data grids and interpolation techniques to such circuits can cause the generated model to suffer from either "undersampling" or "oversampling." With undersampling, too few data samples are collected and the model is not completely defined — especially close to resonance, where the behavior changes rapidly with changing frequency. In an effort to be sure that enough data are collected in this one critical area, the model may suffer from oversampling, with too many data samples and inefficient model generation.

A model composer

As an alternative to building classic analytical models, engineers can use a full-wave EM modeling tool to fully characterize a given passive component. This method permits accurate characterization of the actual passive structure to be used, accounting for higher-order mode propagation, dispersion and other parasitic effects. However, the calculation time required for full-wave EM simulation of a given component makes real-time circuit tuning impossible.

This model accuracy dilemma has been addressed by a new model generation technology that combines the speed of analytical models and the accuracy of full-wave EM simulation by creating a compact parameterized passive model (see Figure 1).

This article is based on a model composer that is a next-generation, highly computationally intensive simulator. It combines the accuracy of EM simulation with the speed of analytical models by creating a single compact model built on specific process information, the desired frequency range and a set of pre-selected model parameters. The finished models are a design kit library, which is accessible to all designers who are using the same process.

Modern modeling software takes advantage of computer advances by being wizard-driven. Wizards help make it mistake-proof. Users can select the model type, frequency range, process properties and the required associated parameters. Once this set of information is supplied through the wizard, the rest is done automatically.

The final compact models have the accuracy of EM simulation while maintaining the ultra-fast simulation speeds typical of standard analytical models. This combination brings increased accuracy to performance-enhancing and time-saving design automation techniques, such as real-time tuning and optimization.

High-performance modeling systems allow designers to bypass the traditional limits of generalized passive models that only work for limited frequency ranges and substrate properties. Additionally, there is no longer a need to make the big investment of time and resources to develop their own models. Models can be generated to build complete passive component libraries tailored to the frequencies of interest and specific process properties. These model libraries can be shared with colleagues and customers, allowing them to achieve the same design accuracy in their contributions to the design process.

Next-generation techniques

The advantage of such modeling software is that it is possible to build a global-fitting model of the chosen parameters, handling frequency and geometrical dependencies separately.

Geometric dependencies are modeled using multidimensional polynomial fitting techniques, while frequency dependencies are handled using polynomial fitting techniques. The modeling process does not require any prior knowledge of the circuit under study.

Adaptive algorithms are combined to efficiently fit a model to the parameters, satisfying the predefined accuracy requirements. This process includes the adaptive selection of an optimal number of data samples along the frequency axis, as well as in the geometrical parameter space. It also includes adaptive selection of the optimal order of the multinomial-fitting model. The number of data points is selected to avoid oversampling or undersampling. The algorithm converges when the desired accuracy is reached. The model complexity is automatically adapted to avoid overshoot or ringing, and the model covers the whole parameter and frequency space, making it easily used for optimization purposes.

Steps for building a model

1. The frequency response of the circuit is calculated at a number of discrete sample points using a full-wave EM simulator. Using adaptive frequency sampling (AFS), a set of frequencies is selected and a rational model for the S-parameters over the desired frequency range is built (see Figure 2).

2. A multinomial is fitted to the S-parameter data at all frequencies (see Figure 3).

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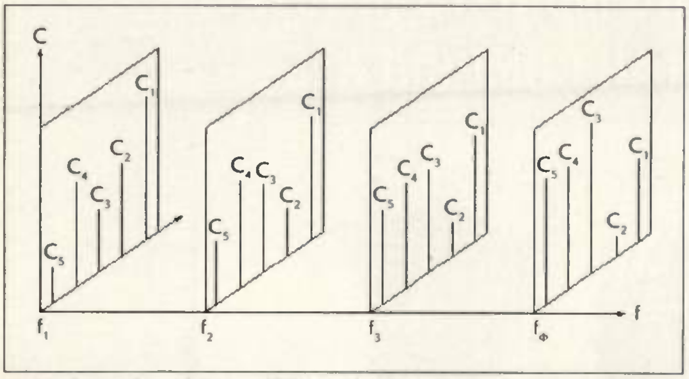

Figure 4. Creation of the coefficients of orthogonal multinomials at discrete frequencies.

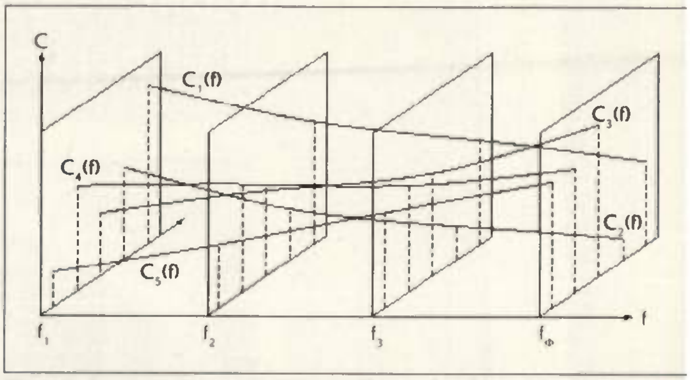

Figure 5. Calculation of coefficients of orthogonal multinomials over the entire frequency range.

3. This model is written as a sum of orthonormal multinomials. The coefficients preceding the orthonormal multinomials in the sum are frequency-dependent (see Figure 4).

4. Using the models built in (1), the coefficients can be calculated over the whole frequency range (see Figure 5). These coefficients, together with the orthonormal multinomials, are stored in a database for use during extraction afterwards.

Comparing modeling methods

To present a typical procedure, the low-pass filter of Figure 6 is simulated using standard analytical models, a full-wave EM simulation and, finally, a simulation using discontinuities built using a model composer.

The filter incorporates two types of microstrip discontinuities that would benefit from more robust models — a cross and an open. The new model development process begins by using a wizard user interface to define the substrate information, model types, frequency range, the required component parameters and their desired range of values. The model information is shown in Table 1.

Model	Parameter	Min.	Max.
Cross	Width1	20 mil	45 mil
	Width2	20 mil	45 mil
	Width3	20 mil	45 mil
	Width4	20 mil	45 mil
	Frequency	0 GHz	20 GHz
Open	Width	20 mil	45 mil
	Frequency	0 GHz	20 GHz

Table 1. The parameters used to define models to be built by the Model Composer.

Once this information is entered via the model composer wizard, the rest of the process is automatic and runs in

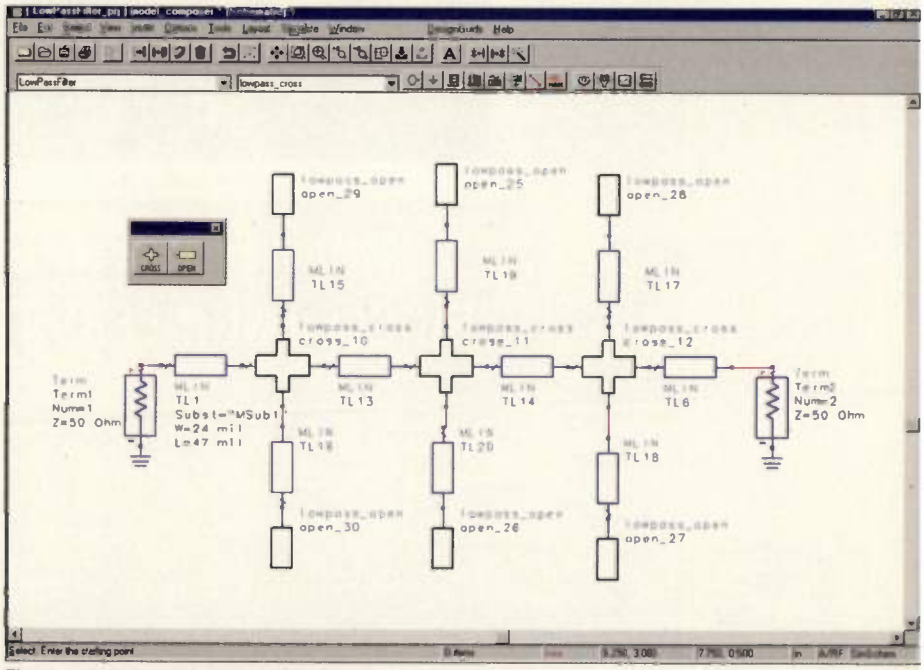

Figure 6. An example lowpass filter design.

Figure 7. New models developed and stored for reference.

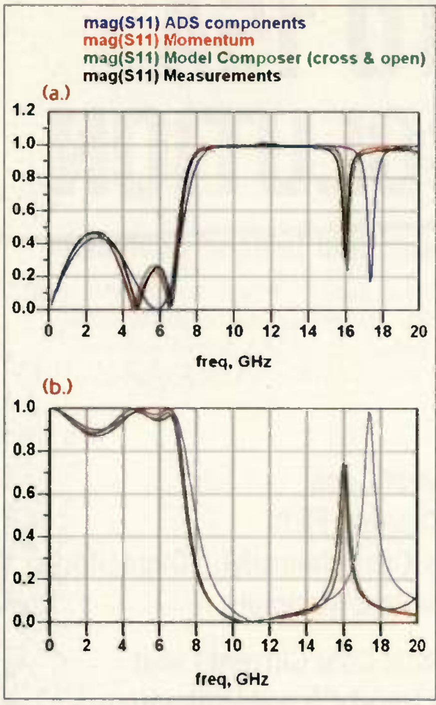

Figure 8a. A comparison of S11 simulations and measurements of the lowpass filter shows that models obtained from Model Composer give results that agree with EM-based simulation and measured data. **Figure 8b.** This comparison of S21 simulations and measurements illustrates how standard microstrip models deviate from more accurate models (and measurements) at higher frequencies.

the background. The final results are two compact models of the cross and the open, stored in the design kit folder (see Figure 7) with associated electrical models, palette bitmaps, schematic symbols and layout artwork. To verify the model's performance, the filter example was simulated using standard microstrip analytical models, with the EM simulator and with the newly developed models from Model Composer. Results of these simulations are displayed in Figures 8a and 8b, along with measured results.

These figures show that simulation using models generated by such software have an accuracy comparable to both momentum and measured data

Summary

The simulation speed of analytical models is combined with the accuracy of EM-derived passive models in the latest generation of modeling software.

Using such tools, designers can develop improved models based on specific operational and material properties. These technologies and state-of-the-art simulators automate the process of accurate model generation.

The low-pass filter example illustrates how simulations using models created in this way maintain both accuracy and speed.

RF

About the author

Mounir Adada is the Agilent EEsof EDA product manager for physical design and MMIC design flow. Mounir has been with HP/Agilent product marketing group since May 1997. Since, he has been involved in various physical design EDA solutions, covering signal contamination, high-speed digital design and 2.5 D electromagnetic (momentum) design and verification products. He can be contacted at: *mounir_adada@agilent.com*. To learn more about Model Composer and ADS 2002, visit: **www.agilent.com/eesof-eda**.

References:

[1] "Constrained EM-Based Modeling Of Passive Components" T. Dhaene, J. De Geest and D. De Zutter, IEEE International Microwave Symposium 2002 (IEEE IMS 02)

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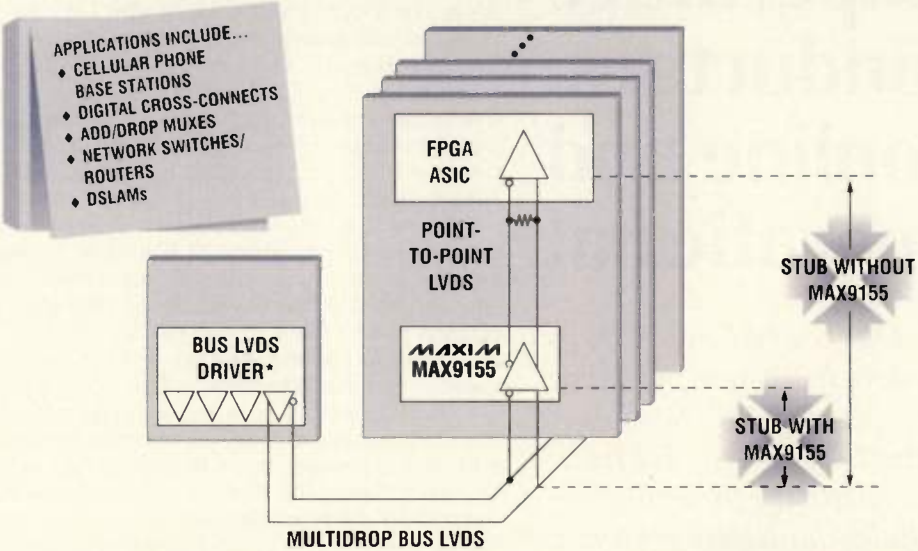

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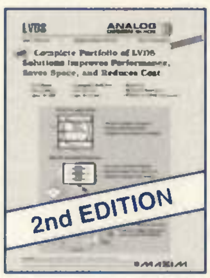
- Low 10mA Supply Current
- Low 6mA Supply Current in Fail-Safe
- 0.6ns (max) Chip-to-Chip Skew

PART	INPUT	OUTPUT	GUARANTEED DATA RATE (Mbps)	MIN OUTPUT RISE/FALL TIME (ns)	ADDED RANDOM JITTER (ps$_{RMS}$)	ADDED DETERMINISTIC JITTER (ps$_{P-P}$)	PIN-PACKAGE	PRICE† ($)
MAX9155EXT-T	LVDS	LVDS	200	0.5	0.6	23	6-SC70	0.95
MAX9156EXT-T	LVPECL	LVDS	200	0.5	0.6	23	6-SC70	0.95

†2.5k piece price provided is for design guidance and is FOB USA. International prices will differ due to local duties, taxes, and exchange rates. Not all packages are offered in 1k increments, and some may require minimum order quantities.



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INFO/CARD 91

High-temperature superconductors: online and operational

Discovered more than 15 years ago, high-temperature superconductor (HTS)-based products have moved from laboratory curiosity to practical, field-deployed systems.

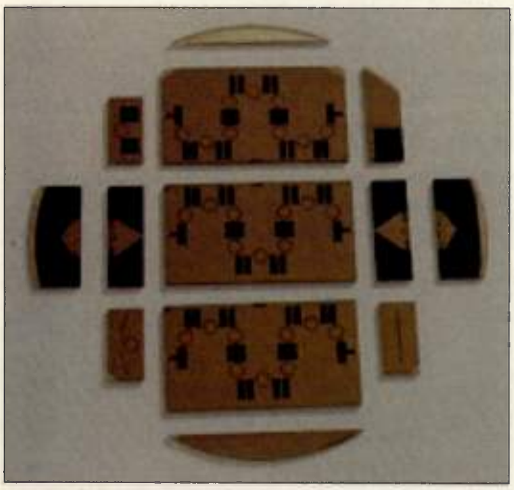
By David R. Chase

Dutch physicist Heike Kamerlingh Onnes, Nobel Prize winner in 1913 for his low-temperature research, discovered superconductivity in 1911. The effect was first observed in mercury wire when it was found that the electrical resistivity suddenly disappeared when the wire was cooled to below a temperature of about 4 K (–269° C).

Onnes proved that resistance vanishes by showing that a persistent current flows indefinitely in a ring or solenoid with no voltage applied.

Critical temperature — ground zero

Critical temperature, T_c, is defined as the temperature below which 100% of the material under examination becomes superconducting. Figure 1 shows a representative plot of resistance vs. operating temperature.



An HTS thin-film wafer after deposition, patterned, etched and diced.

Until 1985, the highest T_c with elements or alloys was ≈23 K (–250° C), observed in thin films of Nb3Ge. Because of the low temperatures required to become superconducting, they became known as low T_c superconductors (LTS).

In 1986 and 1987, a new class of "High T_c" superconductor (HTS) compounds was discovered. The first HTS material was discovered in 1986 when Müller and Bednorz of IBM's Zurich Lab announced a superconducting oxide at 30 K. In 1987, Paul Chu of the University of Houston announced the discovery of a compound Yttrium Barium Copper Oxide (YBCO), which becomes superconducting at 90 K. The next months saw a race for even higher temperatures that produced bismuth compounds (BSCCO), superconductive to 110 K, and thallium compounds (TBCCO) superconductive to 127 K.

One of the largest benefits gained from the increase in T_c from about 23 K for low T_c superconductors to 127 K for high T_c superconductors, is that it enables the use of liquid nitrogen as the coolant rather than liquid helium. Boiling liquid nitrogen is at a temperature of 77 K and is both cheaper and more readily available than liquid helium. Furthermore, the warmer temperature spurs the development of single-stage closed-cycle refrigerators and cheaper ways to package the devices to be cooled. Thus, the warmer temperatures enabled commercial development.

HTS material for RF applications

For RF and microwave applications, one of two compounds is principally used: $YBa_2Cu_3O_{7-\delta}$ (YBCO) or $Tl_2Ba_2CaCu_2O_{10-\delta}$ (TBCCO). They can be formed into thin or thick films.

Thick films are polycrystaline and are usually coated on a three-dimensional RF structure. Thin films are usually ≤1µm thick and are epitaxially grown on a substrate to form a single crystal; the resulting HTS wafer is then fabricated into planar RF structures.

Thin-film deposition can be accomplished in a number of ways, but the most popular are pulsed laser deposition and co-evaporation, depending upon the material used.

Specialized materials such as $LaAlO_3$ and MgO are usually selected for the substrate. In addition to having good microwave properties ($LaAlO_3$ has ε_r=23.4, tan $\delta < 10^{-5}$ at 10 GHz and 77 K; and MgO has ε_r=9.7, tan $\delta < 10^{-6}$ at 10 GHz and 77 K), these compounds have material properties important for single-crystal HTS thin film growth.

Specifically, the so-called lattice spacing of these materials is chosen to be close to that of the HTS crystal. This facilitates epitaxial growth on the substrate with minimal defects in the crystal. In addition, these compounds are chosen because their coefficient of thermal expansion (CTE) closely matches that of the HTS thin film. Because the HTS wafer is subject to such a large temperature range (+400° C in fabrication to –196° C during operation), a good CTE match is required to keep the film from cracking due to thermal cycling.

For most thin-film HTS microwave applications the substrate is ground to a carefully controlled thickness. The HTS material is then epitaxially grown on both sides of the wafer. The wafer is usually then patterned into the RF circuit, undergoing several photolithographic and fabrication steps that

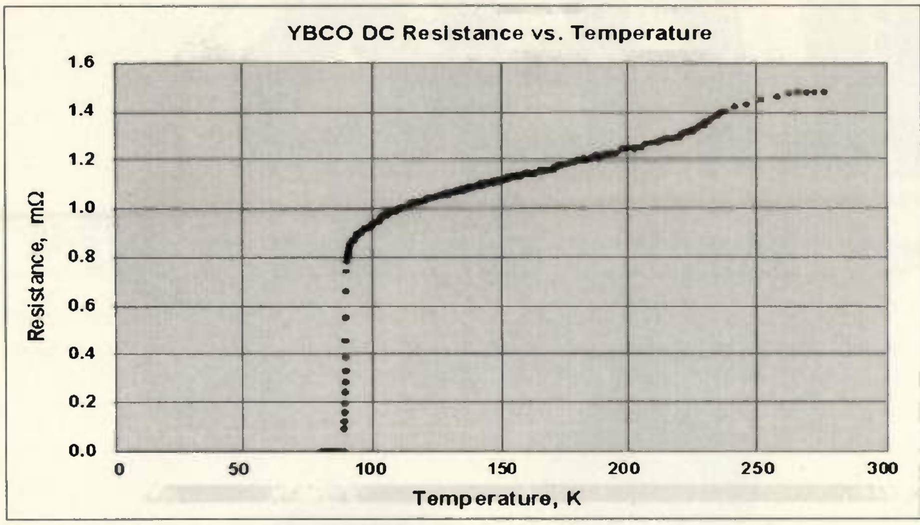


Figure 1. Resistance vs. temperature of YBCO.

result in a superconducting filter microchip. Current wafer sizes used in the production of HTS thin-film fabrication are typically 2 inches in diameter. Some 3-inch wafers have been made in prototype level for research purposes. The lead graphic on page 26 shows a typical 2-inch HTS wafer after it has been patterned and diced.

RF properties of HTS material

HTS resistance drops to zero for DC current, but it does not drop completely to zero for RF current. Figure 2 shows the surface resistance of YBCO thin-film operating at 77 K at different frequencies. For reference, the surface resistance of copper, both at room temperature and at an operating temperature of 77 K, is also included.

The surface resistance vs. frequency of copper shows the expected dependence. However, the HTS material shows a dependency. This implies that HTS is better suited for microwave applications <100 GHz. Nevertheless, despite the increased dependence on frequency at 1 GHz, the surface resistance of HTS is three orders of magnitude lower than copper at the same 77 K operating temperature. Due to this low HTS surface resistance, RF filters can be built in planar technology with a high degree of miniaturization, high selectivity and low insertion loss.

Unlike a typical normal metal like copper or silver, the HTS crystal is anisotropic. As such, super currents are preferentially conducted along one plane of the crystal. One consequence of this can be seen in how the surface resistance (R_s) changes with increasing crystal uniformity (see Figure 3). While thick-film HTS provides a decreased surface resistance compared to copper at 77 K, growing HTS as a single crystal improves R_s by at least two orders of magnitude.

When resonators and filters are carefully designed to take full advantage of the low surface resistance, high unloaded resonator Qs can be achieved.

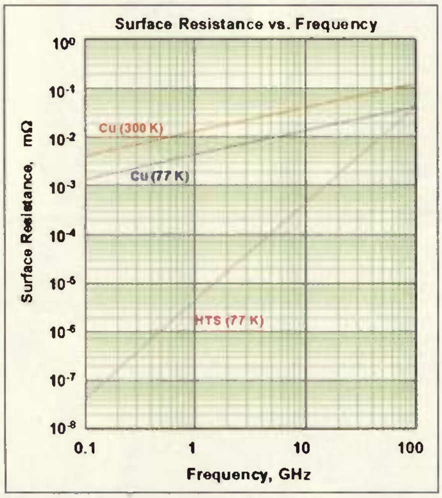


Figure 2. Surface resistance vs. frequency for YBCO and copper.

For 850 MHz cellular applications, for example, resonator Qs in production filters have been measured at around 100,000. Laboratory measurements on some advanced resonator designs have been repeatedly measured at more than ≈400,000.

It is well known that the HTS material will superconduct as long as the operating temperature of the material is below T_c. As the temperature is increased above T_c, the material will cease acting like a superconductor. However, a lesser-known phenomenon is that exceeding a maximum critical current density (J_c) or critical magnetic field strength (H_c) can destroy the superconductive state. Thus, a combination of three conditions must be met for the material to exhibit superconductive behavior. They are:

- *The material must be cooled to below T_c.*
- *The current passing through a given cross-section of the material must be below J_c.*
- *The magnetic field to which the material is exposed must be below H_c.*

These conditions are interdependent and define the environmental operating condition for the superconductor. Figure 4 provides a pictorial representation of this.

J_c and H_c are significant to the RF filter designer for a number of reasons. Perhaps the most significant is that these, in conjunction with the resonator design, will determine the power handling capability and non-linear performance of the resulting filter. A detailed discussion of how these parameters influence resonator design and the resulting impact on filter performance is an ongoing area of research.

Nevertheless, some general observations can be made. For a given resonator and filter design, materials with higher J_c and H_c will be able to handle higher power. Conversely, from a desired power-handling perspective, J_c often influences the minimum size of a resonator. From a straight materials perspective, higher crystal uniformity directly translates to higher J_c and H_c.

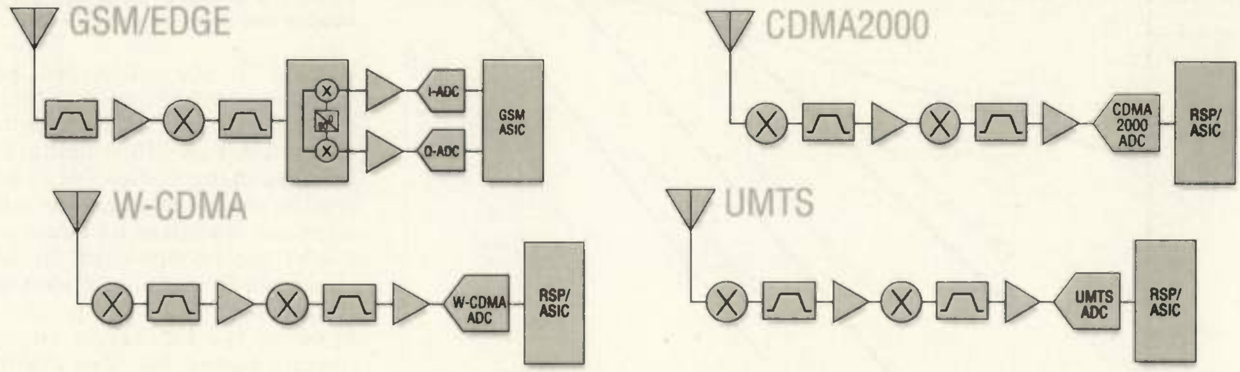
Applications

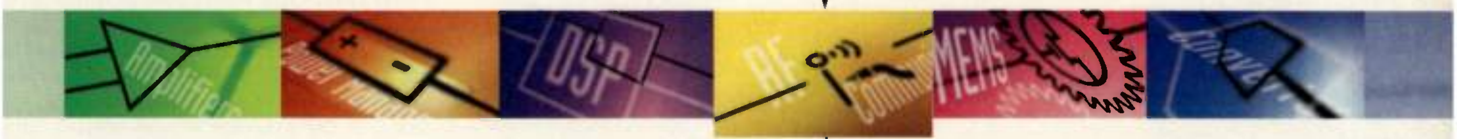
To date, the majority of thin-film HTS product development has been focused on receive-enhancement applications of various sorts. It would be prudent to examine some aspects that make these HTS systems unique.

Deep-space network interference mitigation: In this early HTS application, a low-loss, highly selective narrow bandwidth filter was needed for the deep space network to eliminate interfering signals that reduced sensitivity to the required signals. Because this network had to detect weak signals, the input noise figure was minimized by cryogenically cooling the front end below 20 K. Thus, HTS filters were ideal for this application, as compact designs can be achieved that exhibit minimum insertion losses of fractions of a dB. A portion of the filter design mask is shown in Figure 5, with the measured RF response shown in Figure 6.

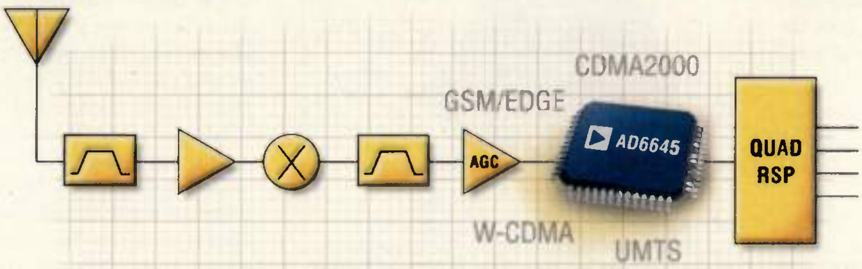
For room temperature operation insertion loss and corresponding noise

Multiple air standards, multiple converters.





Multiple air standards, one converter.



AD6645 RF Receiver ADC

Reducing part count and overall costs while increasing base station reliability has become a necessity in today's market. The AD6645 is a 14-bit, 105 MSPS ADC that enables direct IF sampling without costly downconversion stages. It achieves 100 dB multitone SFDR performance and allows users to digitize multiple air standards such as CDMA2000, W-CDMA, GSM/EDGE, and UMTS in just one chip. So, for high-speed, high-bandwidth, low-noise wireless solutions, simplify your designs with Analog Devices. ***To learn more about the AD6645 and the rest of our high-performance RF IC portfolio, call 1-800-ANALOGD or visit our website.***

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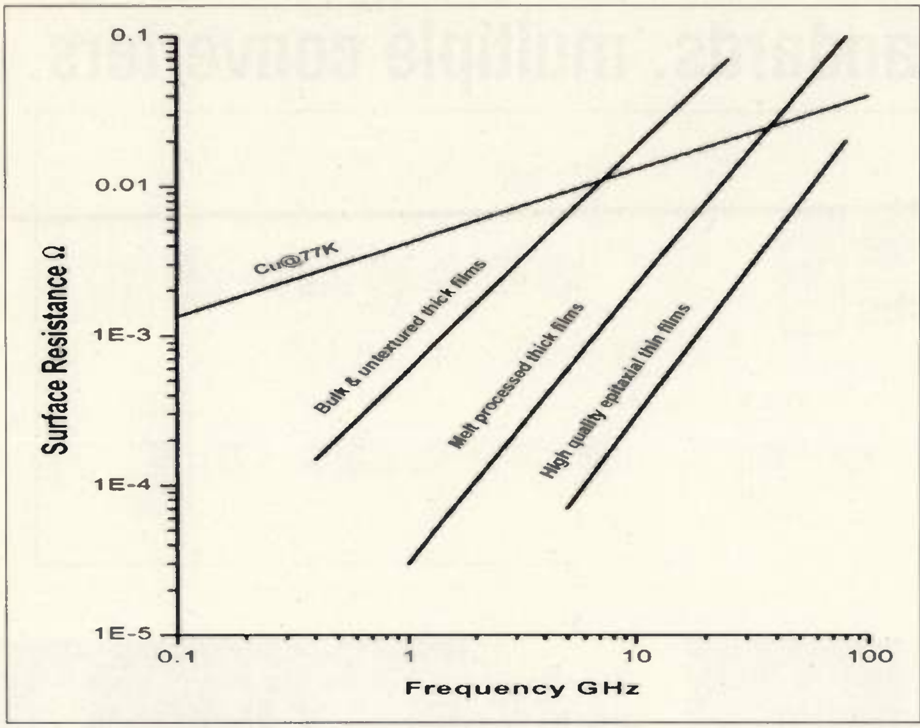

Figure 3. Surface resistance of YBCO thick and thin films vs. frequency.

figure are often treated as synonymous. This is not a bad approximation for normal ambient temperatures. However, for operation at 77 K — or even colder — the fundamentals need to be examined a bit more closely.

It can be shown that the corresponding noise figure (NF) of a given loss in dB when operated at a temperature in Kelvin is given by:

$$NF_T = 10\log_{10}\left(1 + \frac{T}{290}\left(10^{\frac{L}{10}} - 1\right)\right) \quad (1)$$

Equation (1) is plotted for various operating temperatures in Figure 7. For a 1 dB insertion loss, the corresponding noise figure is 0.29 dB at 77 K, and 0.08 dB at 20 K.

Aside from having the benefits of a reduced noise figure for any insertion loss, it also has the effect of "flattening" the filter's noise figure response. For example, if a filter's mid-band insertion loss was 0.5 dB, and band edge insertion loss was 1.0 dB, at 77 K, the equivalent noise figure would be 0.14 dB and 0.29 dB, respectively. Not only does the magnitude decrease, but the variation across the filter becomes less.

Wireless (cellular) coverage and capacity extension: Wireless service providers build cell sites in a given area to provide service to their subscriber base. Customers with wireless handsets communicate to a nearby base station, which then passes the traffic on to another wireless subscriber or to a wired network (either the phone system or the Internet).

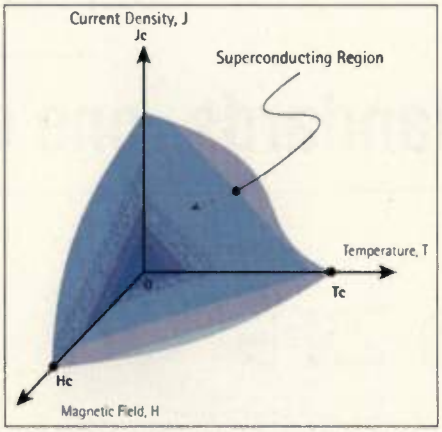

Figure 4. Operating region for HTS superconductivity.

Each active conversation on the wireless network has two directions: an uplink, which communicates from the handset to the base station; and a downlink, which communicates from the base station to the handset. With a few notable exceptions, cellular systems are largely frequency division duplexed (FDD), that is, the uplink and downlink are transmitted simultaneously but on different frequencies.

On the downlink side, base stations use power amplifiers and directive antennas to provide a strong signal in the area that a particular cell site is serving. On the uplink side, however handset power is severely limited fo several reasons. For example, saf absorption rate (SAR) limitations, se by regulating bodies for safety an health reasons, constrain the maximun allowable amount of RF power to whicl a user can be subjected. In addition maximum RF power is often deliberate ly limited to help reduce the powe draw on the battery in an effort t improve battery life. This improvemen will increase talk time and decrease th size of the battery required.

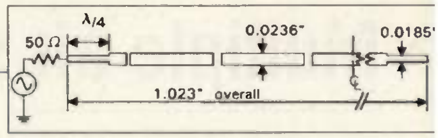

Figure 5. A portion of the design layout for th stripline deep space network HTS filter.

The consequence of this is that cellu lar systems are often uplink limited. I some sense, coverage, capacity, or qual ity of service is primarily limited by th RF path from the handset to the bas station. This is especially true in th 2.5 and 3G systems where voice traffi and high-speed data are carried.

One way of improving the uplink i to improve the base station sensitivit by adding a filter and low-noise ampli fier (LNA) at the RF input of the bas station. A first-stage LNA with a lov noise figure essentially establishes th noise figure for the rest of the receive and improves the uplink budget However, unless the first stage ha enough selectivity to reject the adjacen non-power-controlled bands, degrade large signal performance may result.

Figure 8 shows the receive band allo cation for the 850 MHz cellular receiv band in the United States from the per spective of an "A"-band operator. Th green segments are the portions of th band in which the power received i from A-band subscribers. As such, th power the A-band base station receive is under the A-band base station's con trol. Power received in the remainin

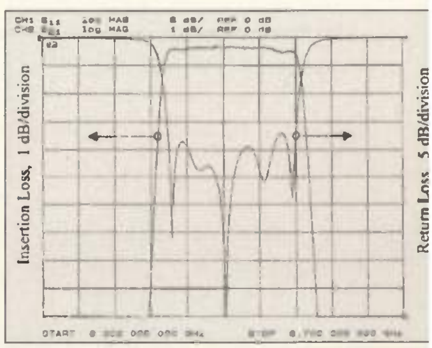

Figure 6. Measured response of the deep spac network HTS filter.

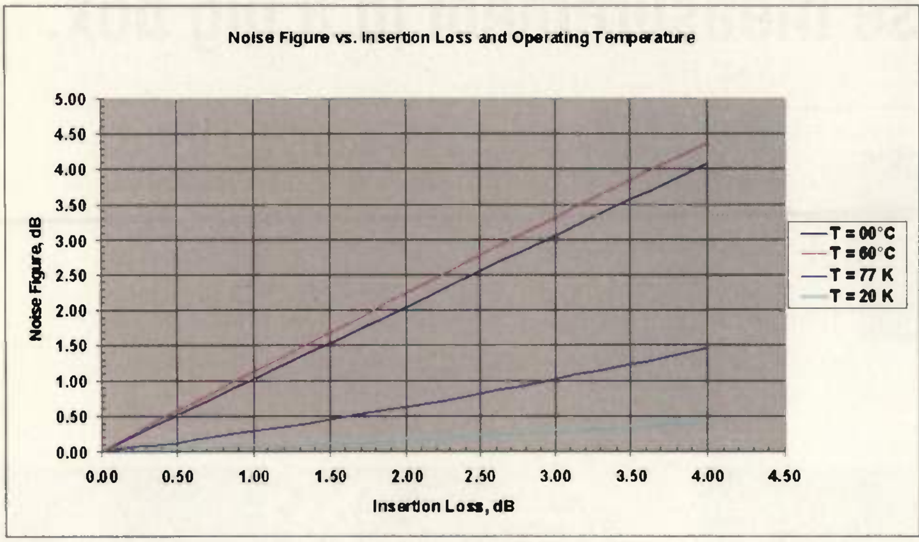

Figure 7. Noise figure vs. insertion loss for various operating temperatures.

portions of the band is transmitted from other services' handsets. As such, they are not controlled by the A-band base station.

By creating a filtering function that passes only the power-controlled signals and rejects all other non power-controlled signals, the receiver gain can be re-optimized for the in-band dynamic range. Conventional filtering can be constructed to provide the desired rejection (using combine or dielectrically loaded cavity-based technologies), but these filters are typically large and will degrade the front-end noise figure.

However, an HTS front end, such as that shown in Figure 9, consisting of a parallel arrangement of two bandpass filters, followed by an LNA, is ideal for this application.

Two high-Q HTS filters provide the required selectivity and low insertion loss. The A' + A bandpass filter is a 10-pole, six transmission zero filter design. Figure 11 shows the design mask and dimension of the filter.

The LNA is optimized for operation at 77 K. The reactive manifolds and the interconnections within the assembly all operate at 77 K, which further reduces the internal noise generated. The result is a high selectivity with a measured noise figure of 0.5 dB connector-to-connector. Figure 11 shows the measured response of the resulting filter/LNA combination.

Applying this to the front end of a base station provides sensitivity improvement with minimal risk of non-linear distortion from the high out-of-band signals. The net benefit to the cellular networks is better uplink coverage with fewer holes, resulting in fewer dropped calls and higher usage. For code division multiple access (CDMA)-based cellular systems, because of a phenomenon known as "cell-breathing" in which the coverage of the base-station "shrinks" with increased usage, improving the uplink can also be translated to

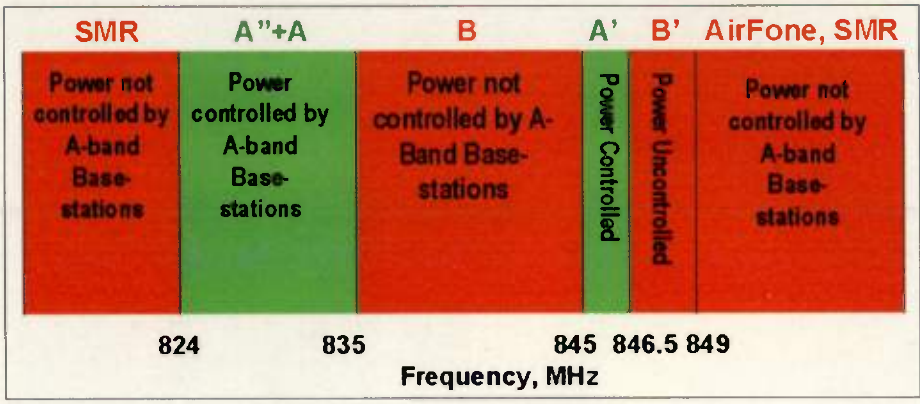

Figure 8. 850 MHz cellular receive band, from an A-band operator perspective.

uplink capacity improvement.

Third-generation wireless (cellular) base station deployment: The current cellular standards (often referred to as

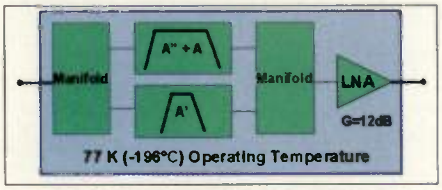

Figure 9. Block diagram of cellular 850 MHz "A" band filter/LNA configuration.

2G) are mostly focused on the handling of voice traffic, and, in some cases, limited-speed data connectivity. The next generation of cellular systems proposes

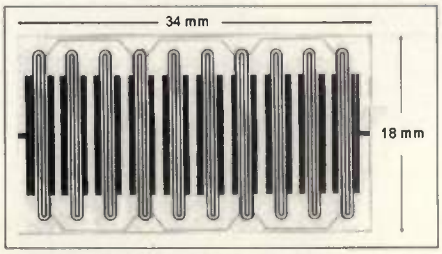

Figure 10. 850 MHz 10-pole, six transmission zero bandpass filter.

to bring high-speed (>128 kb/s) wireless data with "always on" connectivity. However, to make this a reality, the number of base stations required to provide this quality of service is from one and a half to nine times the number of base stations that would be required for an equivalent 2G system deployment

Adding to this are the enormous economic and time pressures of the market. In Europe, billions of euros were spent by the service providers to acquire spectrum licenses in the IMT-2000 licensing auctions. Further, aside from the desire to get the network built as quickly as possible to handle user traffic and help recoup their investment, the service providers are often subject to a government-mandated "complete-by" date that must be met to avoid the loss of the license.

Given these constraints, service providers are interested in decreasing the number of base stations required to accomplish the same coverage and quality-of-service targets. For uplink-limited configurations, sensitivity improvement can be directly translated to the reduction in the number of base stations. Figure 12 shows the percentage of base-station savings as a function of base-station sensitivity improvement for two scenarios: "area coverage," in which the cellular operator is interested in providing service in a given area (i.e., a city), and "linear coverage," in which the cellular operator is providing service largely along a roadway and is not as interested in the surrounding area (i.e., along a highway in a desert).

Complete tower-mountable HTS filter and LNA systems have been developed that provide low noise figures, high selectivity and high sensitivity to 3G applications. This can result in a reduction in the total number of base stations required for initial deployment.

"Digital" receivers: Finally, for emerging applications, there has been a lot of attention given to the software-defined radio. The main idea is to implement as much of the receiver by digital signal pro-

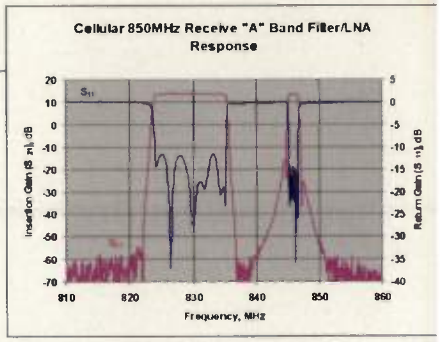

Figure 11. Cellular 850 MHz receive "A" band fil-ter/LNA response.

cessing (DSP) and to minimize the amount of RF hardware needed before it converts to the digital domain and performs the rest of the receiver functions such as detection, synchronization demodulation, etc.

The HTS filter (see Figure 18) passes the power-controlled cellular handset signals and provides enough low-noise amplification to effectively set the noise figure of the receiver. The HTS filter also has enough selectivity to reject the image, so a reasonably high local oscillator (LO) frequency can be used. A conventional IF filter and amplifier further conditions the signal before it is sampled and quantized by the analog-to-digital (A/D) converter.

Because the HTS filter passes only the desired signals that are power-controlled by the serving base station, the dynamic range of the receiver is determined largely by these in-band power dynamic range requirements and not the uncontrolled out-of-band signals.

For CDMA-based systems, this is a comparatively small value because CDMA has tight power control and tends to hug the noise floor in operation. This can have a significant positive impact on the dynamic range requirement of all o

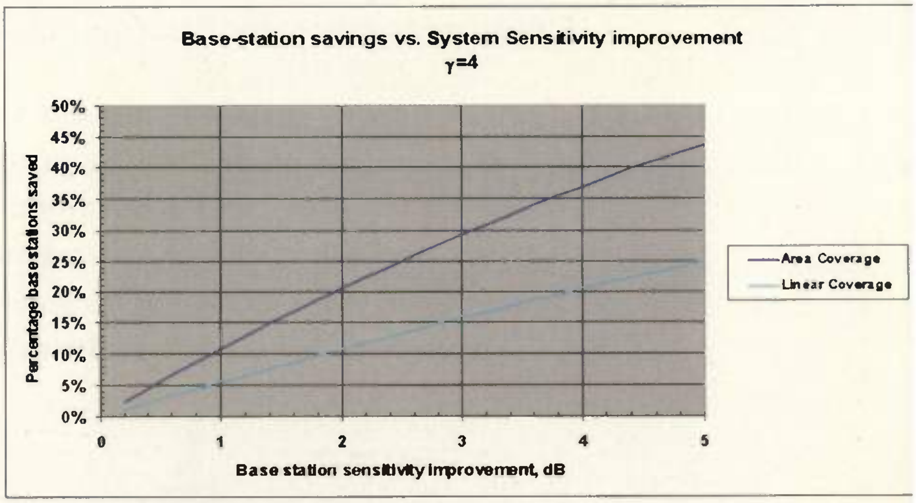

Figure 12. Base station savings vs. individual base station sensitivity improvement.

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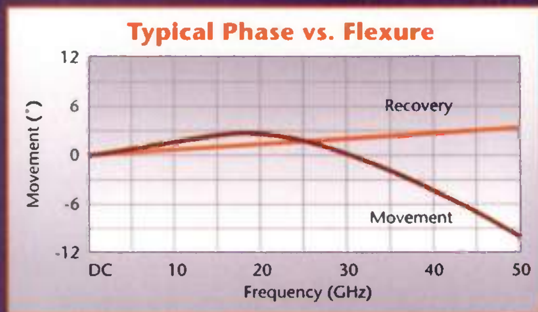

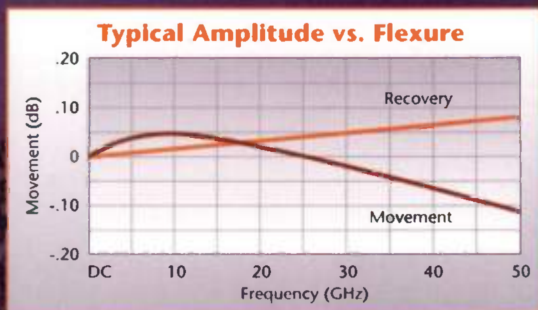

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A Lockheed Martin X-35A Joint Strike Fighter receives fuel from a KC-135 Stratotanker over California's Mojave Desert. (Photo courtesy of DoD.)

Product photos courtesy of:
Hittite
Merrimac Industries
Aethercomm
Alligator Technologies

In This Issue

Editorial

By Lt. Col. Roger Lesser, USAF (ret.)
editor
rlesser@primediabusiness.com

Uncle Sam wants you (and your technology)

Welcome to *Military Technologies 2002*, a special publication from *RF Design*. Why focus on the military? In each issue of *RF Design* we strive to bring you, the design engineer, information that can assist you in doing your job. Our articles focus on presenting technologies and techniques that can improve design capabilities or offer insights into improving efficiencies. Your efforts will guarantee the technologies of the future and the future of communications — and the future of how we win wars. You may not realize it, but you help shape the direction in which military technologies are headed.

Did you ever consider that while you focus on commercial applications, the end user may be fighting a war in defense of our freedoms? It's true. I can give personal testimony, but I'll save that for another time. It's a fact that much of the electronics used by the military comes from commercial development. For those of you who may be unfamiliar with commercial-off-the-shelf (COTS) products, that's where the Department of Defense (DoD) must turn first before it can procure custom or mil-spec parts.

It took the military years to figure that out. It took me a day. As a newly anointed Captain in the USAF, I was once faced with grounding an aircraft because we needed a mil-spec fuse. After spending a frustrating day trying to get one through our supply system, I was faced with the reality that a multi-million dollar aircraft was going to grow roots waiting two weeks for the fuse. As luck would have it, I stopped by a gas station on my way home that night and happened to see a display with fuses. I bought one of each amperage they had. The next day I brought the fuses to the crew chief, who promptly plucked a fuse out of hand, placed in the system and ops-checked it as "good-to-go." When I told him where I got them, he just laughed and showed me the blown fuse. They were identical except for the part identification on the mil-spec fuse.

A simple part that made a difference. With it, we flew. With out it, we were grounded. Such is the case with today's military electronics. Components you see as common, or designed only for use in a given commercial application, can be the component that a DoD designer or contractor is looking for.

The purpose of this publication is to offer the military and commercial designer insights into the technologies, applications and problems facing the military and its suppliers. Amy Cosper, editor for *Satellite Broadband*, offers insights on the successes and failures of satellite communications for the military. Ensuring secure communications is always critical. Authors Lewis Litwin and Sachin Mody offer insight into how to keep "the other guy" from listening in. Many companies have abandoned or ignored the military market. Merrimac Industries' Mason N. Carter shares what his company had to do to adapt to dealing with the "new" DoD. Lastly, you'll find a product section with products that have applications for both commercial and military use.

What you read here is just the tip of the information chain concerning military technologies and applications. In future issues of *RF Design*, *RF Design – The Newsletter* and on the *RF Design* Web site, we will continue to offer more information concerning how you are building the new technology for the warriors of the 21st century.

Roger

Military Technologies 2002

A PRIMEDIA publication

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Communication battleground

The catastrophic results of network interoperability failures in the modern digital theater of war.

By Amy C. Cosper
Editor, Satellite Broadband

The discovery happened 10 years ago during the Gulf War. U.S. President George Bush (father of the current U.S. president) deployed American troops to the Persian Gulf region to fend off the imperialistic maneuvers of Iraqi leader Saddam Hussein. That's when the U.S. military discovered the power of commercial satellite broadcasts and that's how a little-known, sleepy TV network stumbled into infamy. From the war zone, CNN broadcast coverage of Operation Desert Storm. Armchair warriors back in America watched as the war unfolded on the family TV.

But they weren't alone. CNN's broadcast of Operation Desert Storm also served as intelligence for the military.

"CNN was disseminating information faster than the military could process the information. Pilots would land on aircraft carriers and head straight for the 'ready room,' where they were systematically debriefed as they watched coverage of smart bombs on CNN. The information was faster and possibly more comprehensive than what the military could turn around on their secured networks," says Tim Richard, a satellite communications consultant to the defense industry.

The often-painful lessons learned during the Gulf War helped the U.S. Department of Defense create an agenda for the U.S. military's communication networks going forward. CNN became a strategic requirement for future battlefield intelligence.

"As recently as a few years ago, I was riding aboard the aircraft carrier [U.S.S.] Truman, eating lunch with an officer. He said they still use CNN for intelligence and it lags behind the military's network by about five minutes," adds Richard.

CNN may provide intelligence about smart bombs and enemy lines, but it doesn't solve some of the military's most basic communication issues. When engaged in a major theater of war – such as Operation Enduring Freedom – U.S. war fighters are not going into well-established, modern countries with fancy communications infrastructure. That's why satellites are critically enabling devices during expeditionary warfare.

Failures of military communications affect every chain of command across every branch of the U.S. armed forces and its allies – all the way down to the soldier, engaged in combat, who is the one who stands to lose the most as a result

Photo by: Lance Cpl. Nathan E. Eason, 26th Marine Expeditionary Unit.

of communication failure.

Interoperability failures have long plagued the military, but the impact in today's network-centric theatre of war is amplified.

The network kludge

That the military stumbled into its relationship with the commercial satellite broadcast sector is not terribly surprising. That it found a commercial cable news channel to have better intelligence gathering than its own is somewhat concerning.

Navy ships are routinely equipped with C-band broadcast satellite antennas – in receive-only mode for broadcast programming. But there's more: Navy ships haul four or more satellite antennas of varying dimensions for intelligence gathering and communications. That's a lot of antennas and a lot of information on a limited plot of sea-faring real estate. And it's also part of the problem — the military's ability to process information and data quickly and efficiently is hindered by the myriad of systems and system requirements, and the amount of data being pumped through these networks.

The military's satellite communication and broadcast systems have evolved over the years into a loosely patched together amalgamation of parts – a little commercial satellite capacity here; a military bird there; a proposed broadband satellite there; an iridium here.

It's a mess

Studying a chart of military communication networks is an invitation to insanity. These maps and flowcharts reflect a labyrinth of military satellite technology stapled to commercial satellite capacity; all operating at different frequencies and little, if any, interoperability.

It is this issue, this single addressable issue, that needs resolution – not only on paper as part of a theoretical Global Information Grid (GIG), but in practice, out in the battlefield where soldiers are waging wars. Information requirements and needs are great, and growing at every level.

"The military has long had stovepipe systems with a single focus and function. Today there are a number of separate military systems, and none of them are interoperable. You have different terminals to access different satellites. Some operate at different frequencies and the terminal designs are quite different," notes Mary Ann Elliott, president and chief executive officer of Arrowhead Space and Telecommunications, a telecommunications consulting agency out of Falls Church, Va.

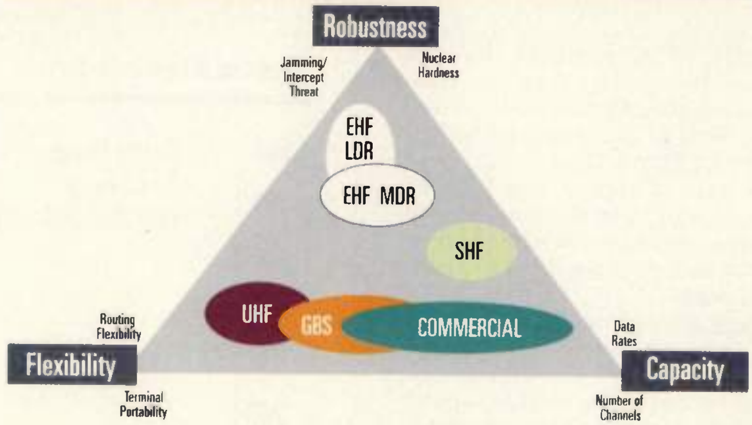
"Interoperability has not even begun. The GIG proposes to cover the globe in a meshed network with complete access to broadband and narrowband systems, but it does not address standards or interoperability issues," Elliott adds.

The need for bandwidth and bandwidth-gobbling military applications is growing. There's more information to process — images, video, data, secured information, basic voice — and more need for expediency. In fact, the military's bandwidth requirements from Desert Storm to Operation Enduring Freedom have grown a staggering 663%, according to Col. Barry Patterson of the U.S. Air Force.

"What we have is information demand surpassing our resources," Col. Patterson added during a military conference last month, noting that when the war broke out in Afghanistan, the U.S. military didn't have enough satellite capacity over the region, so it turned to the commercial providers, who moved customers off Indian Ocean region satellites to accommodate the military's communication needs.

"The military turned to commercial providers for coverage during Operation Enduring Freedom. [The military] tapped PanAmSat, for

Why different systems?



Source: UASF Col. Barry Patterson presentation, Mitcom 2002.

Types of Satcom

FLTSAT/UFO	GBS	DSCS	Milstar	Commercial
UHF	Ka-Band	SHF	EHF	C, Ku, Ka
▪ Lightweight, mobile ▪ LDR ▪ No protection ▪ LMI ▪ DAMA increases user access	▪ New segment ▪ Added comms payload on UFO ▪ High throughput ▪ Small antennas ▪ Small push/pull data broadcasts	▪ High data rates for tactical and enterprise ▪ User demand growing - Imagery - Video - Telemedicine ▪ Limited AJ protection	▪ Protected comm for the warfighter - [AJ, LPI, LPD, EMP] ▪ LDR/MDR ▪ MDR: C2 range extension ▪ Crosslinks - no ground relay stations ▪ DSCS JRSC/SCT	▪ Growing capability ▪ High throughput - Imagery - Video -Telemedicine ▪ No protection ▪ Pay for services ▪ Mobile (LDR) ▪ Ka: Possibility for GBS III

Source: UASF Col. Barry Patterson presentation, Mitcom 2002.

example. The military had to increase its capacity from the commercial sector to meet demands," notes Andrea Maleter, technical director for Futron Corp.

This type of requirement is called a surge. And it is common during war times, because the military does not own sufficient bandwidth to satisfy its needs.

"There are certain times you need additional capacity — particularly during times of war. It challenges the kind of resources you need to support battlefield activity. Wars are indiscriminate. They may breakout anywhere – in places where the military has little capacity," notes Carissa Bryce Christensen, managing partner at Tauri Group.

Christensen adds that this leads to interoperability issues among commercial space systems.

"One terminal may not be compatible with another terminal that you're using for military systems. This is a huge problem if you've got a proliferation of mechanisms to receive data in a mobile environment," Christensen notes. "But the truth remains that it comes down to this: Satellites provide instant infrastructure. It's powerful and extraordinary, but still, there are issues."

Souls in the foxhole

Soldiers are instructed to "move, shoot, communicate," in precisely that order, during combat. If a war fighter must pause to find radio signals or take commands, he becomes a sitting duck.

It has happened before during U.S. military action — in Mogadishu, Somalia, in the Gulf War, the Balkans and during the Iranian hostage crisis.

During the Persian Gulf War, for example, U.S. fighters didn't have enough bandwidth to suit their data requirements. At times, they had to stop, during combat, to communicate with command and control, a blatant breech of "move, shoot, communicate."

When communications fail, lives are lost, and it's preventable through interoperability. That's the startling part.

"The scene looks like this — the soldier in the foxhole — he's talking into one system, then he puts it down and listens to another device, then he puts that down. It would be like talking on your cell phone and then passing that call over to a landline; you then put the cell phone down and retrieve it off the landline. Except, in this scenario, you're not getting shot at," notes Elliott.

"This poor soldier radios in for positions, tries to communicate over two or three different devices. He's calling in to identify drops for smart bombs; he's talking over different radio systems and satellite networks. It's easy for mistakes to happen," continues Elliott. "If one system goes down and a soldier can't receive or move communications to another device under hostile conditions, that soldier doesn't have too many luxuries. He's carrying all this equipment and none of it works together."

Too much information

The nature of modern digital war demands that expeditionary warriors are deployed. That means soldiers do battle away from home and depend on instant infrastructure for communications.

"Adversaries won't be expeditionary. Modern wars have taken place in bandwidth-poor countries. When you're indigenous to a region, military tactics are different. In these wars, our troops are not indigenous," says Col. David A. Anhalt, chief, space control and advanced technology for the U.S. Air Force.

That's why satellites and instant infrastructure are so vital to wartime strategies and communications.

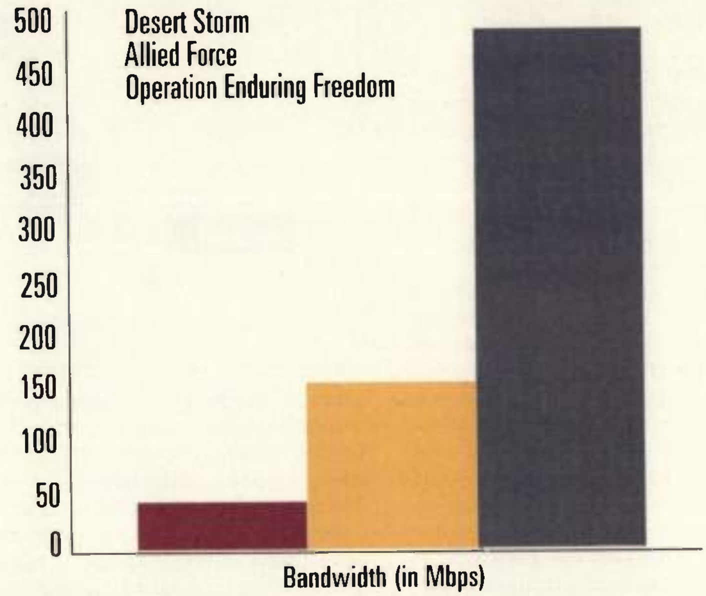
"There are several countries with fiber — fiber that comes into a major point of presence. But all the terrorists would have to do is blow up that point of presence and all communications are disrupted. If power plants are destroyed, the government can haul in generators. The military must be self-sufficient. That's why satellites are so viable and vital," says Elliott.

Operation Enduring Freedom is a network-centric war, according to Richard.

Bandwidth requirements are higher than during any other military operation.

"There's too much information to process. Too many systems. Too many devices. Too many antennas. Too little interoperability. The military needs to say 'O.K., what's important here?' Information management needs to take place down to the lowest level. This absolutely requires standardization," notes Richard.

Expansion of bandwidth demand



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In the interest of American and Allied soldiers and American taxpayers, the military can begin to eliminate certain communication problems by cracking down on wastes.

"The military needs to look at what it's wasting. It needs to be more efficient. What we've got is different people at different levels singing the same song and nobody is doing anything about it," says Richard.

Elliott agrees and adds: "We must work toward a common set of standards so that if our forces are connecting to disparate satellite networks or cellular systems, interoperability is seamless and painless. Where would we be in commercial telecommunications if we had a half dozen phone systems? In my opinion, the military shouldn't buy anything unless it's built with a common set of standards, including intra-military communication systems."

RF

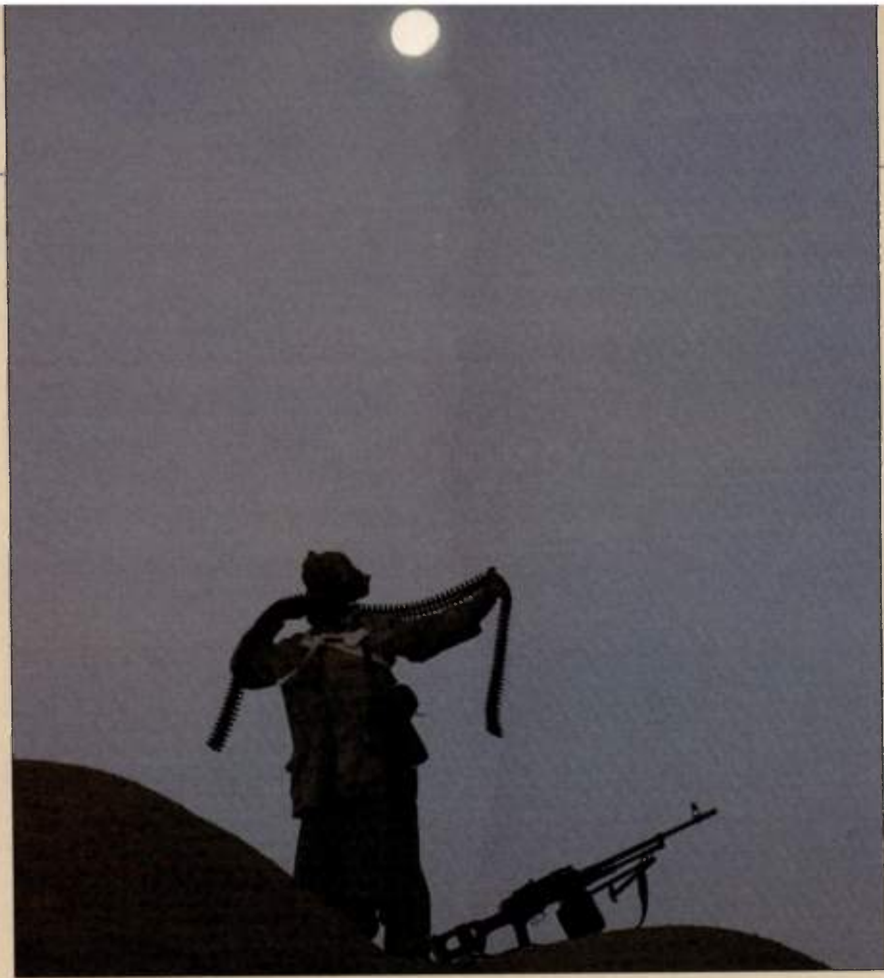


Photo by: PHC Johnny Bivera, Fleet Combat Camera Atlantic.

Maximized network efficiency in stressed enviroments

As military and commercial communication satellite sectors creep toward closing the gaping hole in communication platform standards, there is plenty to spell out.

If there's one thing the U.S. military does painfully well, it's use, create and abuse acronyms. Some military acronyms number in the double digits. But the military may have met its match. There's one community that can out-acronym the military: the Internet standards contingency.

When combined, the sum total of acronyms across military and Internet is roughly pi. And because the military's requirements for bandwidth have exploded over the last 10 years, it is now seeking Internet-world solutions to maximize limited and precious bandwidth resources.

Satellite Broadband asked Eric Travis, chief protocol engineer of Global Sciences Technology (Full disclosure: Global Sciences is the sponsor of this report) to help describe one standard, called SCPS, and how this standard represents a leap forward for Internet protocols in both a military and commercial applications. Travis is a firm believer in the benefits of SCPS – stopping just short of suggesting that the standard should replace TCP.

Q: What is SCPS?

A: SCPS is either Space Communications Protocol Standards or Stressed Communications Protocol Standards. The Department of Defense folks are partial to the latter, and in truth, it is probably more applicable for the deployment domain, as space is a subset of the stressed environments.

The first thing that one notices is that the SCPS profile includes the core of the Internet protocol suite and a set of stressed protocols.

Q: Why isn't a different network protocol IP sufficient?

A: The root of the answer is bit-efficiency. When developing the requirements for communications in stressed environments, a strong driver was the need to reduce transmission overhead.

One should think of SCPS-NP as a compressed format for IPv4 or IPv6 headers for use "only" within the stressed subnets.

SCPS-NP overhead is scalable — you only pay for the overhead associated with the capabilities that you require. SCPS-NP is capable of carrying full IPv4 or IPv6 addresses or mapping the full IP addresses into a smaller space to reduce overhead within the stressed subnetwork.

Q: How does SCPS-TP differ from TCP?

A: SCPS-TP, more appropriately referred to as TCP-Tranquility, really is TCP. In its default behavior, a TCP-Tranquility implementation is a fully RFC-compliant TCP. It

A definition to know for this interview: A stressed environment is defined as a communications parlance for any communications medium that is exposed to negative external effects that result in degraded performance. A wired connection, like Ethernet, for example, is not stressed. It is a controlled, protected, relatively error-free medium. Most wireless communications are stressed because they are affected by weather, various sources of interference, latency and asymmetry. These conditions introduce bit errors and packet loss. Travis contends that because stressed and unstressed media behave differently, they should require different operational protocols that can alleviate or mitigate stress. This is the whole motivation behind SCPS.

includes all the features and capabilities of a modern TCP plus some optional enhancements that allow it to perform more optimally in stressed environments.

Flavors of TCP are generally distinguished by their mechanisms for handling congestion within the network. There is TCP-Tahoe, TCP-Reno, TCP-New Reno, TCP-Vegas, TCP-SACK, TCP-FACK, etc. TCP-Tranquility (named for a desert on the Earth's moon) distinguishes itself in this manner by introducing the ability to handle losses based on corruption differently than those based on network congestion.

To allow us to change our default loss assumption, we had to introduce alternative mechanisms to handle congestion avoidance and congestion control. These same mechanisms turn out to be critical to allowing full utilization of pre-allocated and reserved bandwidth and efficient operation over highly asymmetric paths (where the ratio of forward and reverse bandwidth might be greater than 1000:1).

Q: What are the benefits of SCPS-based solutions?

A: The goal of the SCPS effort was to provide communicating entities with Internet services while maximizing the efficient utilization of scarce resources. Applications can be written and tested using all the tools familiar to us in the Internet environment and later deployed into stressed environments.

When your communications path straddles a stressed environment and a more typical wired, fibered or tethered environment, the key is to isolate the potentially conflicting characteristics of each environment.

An SCPS-based solution provides a transparent (to the end-users) means of maximizing efficiency of operation over the stressed path but maintaining fairness or orderly operations over the tethered network.

Q: How is SCPS used?

A: In many typical deployments, the introduction of SCPS will be entirely transparent to them. A common use of SCPS is the introduction of SCPS gateway boxes at the boundaries of the stressed environment. These gateways terminate TCP traffic crossing the stressed membrane and initiate a new TCP connection better suited to the new environment.

A still rare, but growing deployment scenario is enhancing the TCP implementation on embedded devices (typically wireless devices like PDAs, cellphones, sensors, etc.) to include the capabilities of TCP-Tranquility. Communications among devices within the stressed environment is suitably enhanced. When the communications path penetrates the stressed membrane, the TCP-Tranquility connection is terminated and a new TCP connection is established to traverse the tethered network.

Q: In your opinion, should SCPS (or TCP-Tranquility) replace TCP?

A: In the 17 or so years that I've been using TCP, I've been amazed at how well it works over such a wide range of environments. It isn't always optimal, but it generally does its job in getting collections of bits between points A and B.


Nick Uran and Eric Travis of Global Sciences Technology.

It has always been the desire and expectation of those involved in the SCPS effort that over time the capabilities provided by TCP-Tranquility, such as rate pacing, separation of loss from the signaling of congestion, handling of link-outages... would be incorporated into the evolution of TCP or some widely deployed transport protocol.

Some capabilities, such as rate pacing, can be very beneficial to the health of the larger network, so I think that we will see these introduced into a fair number of TCP implementations in the near term.

This will have absolutely nothing to do with its potential benefits to stressed environments, but we'll all benefit regardless.

Other capabilities and features don't necessarily make a lot of sense for operations outside of stressed environments. The changing of TCP's default loss assumption away from loss = congestion is just a really bad idea when you are operating within the Internet, or even most intranets.

I've been convinced that the right answer is not attempting to have a single one-size-fits-all streaming transport protocol for operations in all environments. The rules of engagement and sharing in some network environments are going to be different. When efficiency is important, perhaps this will lead us toward more tailored transport protocols for different environments.

However, the use of tailored transport protocols for spanning different environments is slightly problematic in that solutions like the deployment of SCPS gateways violate the end-to-end semantics of TCP. We are splitting transport connections in a manner transparent to the ultimate endpoints of communications.

Q: If SCPS are enhancements to the standard Internet protocols, why haven't they been embraced by the IETF?

A: The short answer is that the IETF has never officially seen them. We've yet to bring the proposed enhancements into the IETF for consideration — most of the reasons are fairly simple:

Protocols like SCPS-NP aren't IP-based, and they have no place being introduced into the IETF; The only real difference between SCPS-SP and IPSEC is that SCPS-SP trades a more bit-efficient header structure for a reduced set of possible security associations between endpoints. Most of the capabilities identified for SCPS-FP are already showing up in FTP.

This leaves us with the tallest pole — the enhancements to TCP...With the development of IPv6, there has been a contingent within the Internet community — their desire strong and yen — who would like to begin work on a TCP Next Generation. This has been resisted within the IETF, largely because of the desire not to tinker with the stability of the Internet itself. Since the introduction of congestion avoidance in the late 1980s, modifications to TCP within the IETF have been slow, incremental and careful.

As I mentioned earlier, I'm confident that some of the features incorporated into TCP-Tranquility will be incorporated into a number of mainstream TCP implementations. However, some of the capabilities introduced within TCP-Tranquility can introduce significant behavioral changes to TCP. While we are sure that these work and scale well within our target deployment environment, we're not ready to even attempt to inflict them on the unsuspecting Internet backbone.

Serving the military customer: One company's solution

Many companies shy away from working with the DoD because of the challenging bureaucracy. Learn how one company met this challenge and is providing the military with high-performance components.

By Mason N. Carter
Chairman and CEO, Merrimac Industries

The Joint Strike Fighter program is one of the most ambitious ever undertaken by the Department of Defense, requiring three versions that meet the different demands of the U.S. Air Force, Navy, and Marines. As the successor to the F-16, it must be stealthier, fly longer without refueling, carry more advanced avionics, and be designed within razor-thin cost constraints. So when the first production aircraft takes flight, it will be a significant and perhaps unprecedented achievement. It will also be the crowning achievement for the many RF and microwave designers who have contributed to the successful project.

The Joint Strike Fighter is expected to augment the Air Force's F-22 and the Navy's F-18. This next-generation fighter will depend on COTS technology. (Photo courtesy of DoD)

Challenging though designing and manufacturing the Joint Strike Fighter may be, it is simply the latest and most visible result of a changing defense procurement environment that rewards those companies with the vision, commitment and resources to change along with it. For RF and microwave manufacturers, this transformation has required a wholesale overhaul in the way they approach the military market. Not surprisingly, many have chosen to leave. As one of the companies that has maintained its aerospace and defense commitment, Merrimac Industries has addressed these evolving needs.

A commitment to change

In the nearly 50 years that Merrimac has been serving the defense industry, the company has witnessed many changes in procurement philosophy and purchasing practices. However, the most widespread changes have occurred in the last decade with long-term bipartisan political support, as the military moved to reduce costs by employing readily available products whenever possible, emulating the practices of the commercial sector.

Today, military customers want components and subsystems with increasingly higher integration and performance — and in smaller, lighter, and much cheaper packages. In essence, they require commercial products modified for military applications, with exceptional shielding and the ability to function satisfactorily in environments with wide temperature changes and high levels of shock and vibration. The supplier's long-term commitment to continuing support of the product has become crucial as well, because many manufacturers have opted to abandon defense customers.

When viewed with these needs in mind, suppliers sometimes found that the customer's target cost was less than their bill of materials alone. Clearly, satisfying defense customers in the future would require a clear look at every aspect of operations to determine how labor, inefficiency, and any unnecessary costs could be driven from design, development, and manufacturing, and how different materials could be used. Merrimac was hardly immune to this introspection. However, after a long, hard look at its materials, processes, production and testing, it became obvious that the customer needs could be met, but it would take a top-to-bottom reengineering to achieve them. Merrimac embarked on this program in early 1997 with the goal of meeting customer demands, but in fact actually well exceeded them.

Every section of the company was affected, beginning with a total cultural change. Designers were challenged with learning new design techniques and processes, and providing input required to implement them. Technicians were similarly charged to produce recommendations about how production tasks could be streamlined. The company invested in automated manufacturing equipment that would produce substantial long-term improvements in efficiency and cost reduction. New customer relationship management practices were initiated to better serve the new defense customer. The massive changes made throughout the company required a sustained, concentrated effort, but were still accomplished in a relatively short time. Process improvement programs continue today to further increase productivity and efficiency.

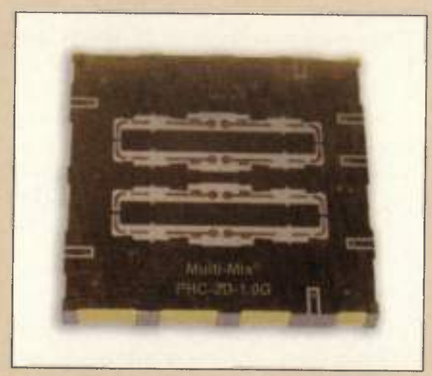
The Air Force's F-22 Raptor is another example of a procurement that uses commercial technology. Merrimac is one of the providers. (Photo courtesy U.S. Air Force)

Custom capability is crucial

It had also become clear to Merrimac that design flexibility was high on the wish list of defense contractors. That is, customers wanted choices and custom designs, yielding the benefits of mass customization. As the reevaluation of its core defense products was nearing completion, Merrimac introduced an entirely new technology called Multi-Mix Microtechnology, based on a preengineered standardized platform concept benefitting customers with lower design cost, faster time-to-market, and proven reliable designs. It is a proprietary multilayer packaging methodology in which fluoropolymer composite substrates are fusion-bonded together to form a multilayer structure of microwave circuits that are a fraction of the size of similar components realized with conventional technologies. Nearly any type of active or passive microwave element, from discrete semiconductors to MMICs, as well as plated-through via holes, can be contained within this structure to form a multifunctional circuit that is a self-contained package requiring no additional enclosure. Multi-Mix architecture provides excellent thermal management.

With this introduction, the company's customers can choose both its core products, which have been reengineered in many cases to reduce cost, size and weight, as well as the new Multi-Mix technology. This technology can be used to produce products with similar functions, but in form factors orders of magnitude smaller, lighter and more cost-effective than is achievable with the traditional RF and microwave technologies. This is especially valuable in new system designs, which can take advantage of the reduced real estate required by Multi-Mix components and micro-multifunction modules. No longer limited by the technological constraints of the past, Merrimac can provide a wide variety of application solutions.

Merrimac subsequently introduced Multi-Mix PICO, which brings together the advantages in manufacturability, repeatability, and performance inherent in Multi-Mix technology, with an additional size reduction of more than 84% and a corresponding reduction in weight. Even though most Multi-Mix PICO products typically measure only 0.18 x 0.18 inches, they can handle an RF input power of 100 W CW with appropriate heat sinking, and match their larger counterparts in every other area of performance as well. The dramatic size reduction inherent in Multi-Mix PICO devices, as well as the ability of the Multi-Mix architecture to allow multiple functions to be integrated in a small space, has been well received in the defense community. Merrimac is currently expanding its Multi-Mix facilities in both West Caldwell, NJ, and San Jose, Costa Rica.



The Multi-Mix PHC-2D-1.0G delay line discriminator is a good example of how collaborative effort with the customer can produce superior results. This integrated multilayer unit, which operates from 750 MHz to 1.25 GHz, replaces discrete designs with better performance in half the size and 5 % of the weight.

A need for enterprise-wide integration

Hardware design was essential, but a holistic approach was required to serve the new defense procurement environment. Specifically, the ability to manufacture large quantities of components at reduced cost was considered essential. To accommodate this, Merrimac established a facility in San Jose, Costa Rica, that could produce the full range of the company's defense products, but even more cost-effectively. Further, to accommodate the needs of very fine-line circuits, especially those used in millimeter-wave systems, Merrimac acquired Filtran Microcircuits of Ottawa, Ontario, Canada. Together, these new resources, along with those in Merrimac's newly-expanded headquarters in West Caldwell, provide defense customers a single resource for a broad array of circuits.

A good example of how this works is illustrated by a power divider subsystem in production at Merrimac that is used in an upgraded phased-array radar. The program is being conducted jointly with Merrimac's RF Microwave Products Group in West Caldwell, Filtran Microcircuits in Ottawa, and engineers at the San Jose, Costa Rica facility. The component requires multiple four-way power dividers to be integrated in a compact module designed to withstand the rigors of a shipboard environment.

The initial etching of fine-line geometry is performed by Filtran, and the boards are sent to Costa Rica where the chip resistors are soldered to the inside of the power divider.

The boards are then returned to Filtran where final processing is performed. The completed assembly is then sent to either West Caldwell or Costa Rica, where small, edge-launched connectors are attached and final testing and inspection are performed.

The result of this process is that the customer reaps the benefits of having complicated work such as fine-line etching performed by an organization uniquely equipped to do so, less complex work performed where it can be most cost-effectively accomplished, and key design and overall project control performed at the company's headquarters.

Relationships are essential

Defense programs such as the Joint Strike Fighter require unprecedented levels of coordination between prime contractors and their suppliers. To meet this need, Merrimac has developed innovative customer relationship programs that reduce the time, cost, and complexity of the procurement process. One of these programs, called Merrimac Space Qualified Products (MSQP), which was initially created to serve the company's aerospace customers, has been adapted by Merrimac to meet the needs of the defense procurement environment. By eliminating many of the proven bottlenecks in the procurement process and removing much of the burden from the customer, MSQP has realized significant reductions in delivery time and cost. It will have similar benefits when applied to the Joint Strike Fighter program, in which the strength of contractor/supplier relationships will play such an important role.

Merrimac has also created an interactive design environment that allows key defense customers to work online from their offices with Merrimac engineers to save time and eliminate miscommunication when creating new designs. Merrimac also makes extensive use of videoconferencing and an extranet for collaborative cross-functional engineering design reviews to reduce cost and maintain schedules.

A major challenge – but worth it

The changes at Merrimac were not simply desirable, they were essential to ensure the company's continued success in serving the defense market. Without them, the company would not today be able to offer the breadth of technology, design flexibility, high-volume manufacturing, and specialized expertise required by new defense programs such as the Joint Strike Fighter.

It is also important to note that the changes at Merrimac have also had a positive impact on its commercial business. In fact, Merrimac's "best defense practices" mirror those of its "best commercial practices," which is of course one of the goals the Department of Defense hopes to achieve.

RF

Working with the military: Where do you start?

Working with the Department of Defense can be daunting. However, things have changed since the mid-90s, when the DoD was mandated by then-Secretary of Defense William J. Perry to buy commercial-off-the-shelf (COTS) technology. Prior to the Perry mandate, DoD designers had to justify the use of non-mil-spec, or non-custom designs or parts. Today the reverse is true. The advantage: significant cost savings.

This was amplified in 1997 with the Defense Reform Initiative that identified as one of its goals the transformation of acquisition and logistics, and the exploitation of advanced technologies. While many companies, such as Merrimac Industries, have maintained a military focus while addressing commercial applications, there are many companies who have not. Yet, many companies exist whose products are designed for use in harsh environments that could also be used by the military. In today's telecom world, that means just about everybody offers a product that can meet the needs of the DoD. But how do you bring the product, or capability, to the attention of the military designer, a designer who may be working for a contractor or one who may be working at one of the DoD's various design centers?

While there are many options, one of the best means is to first keep abreast of what programs the DoD (and also Homeland Security) are advancing. One way of doing this is by monitoring the DoD contracts. This can be done via e-mail or by going on the Web. To request a daily e-mail update go to **www.defenselink.mil/news/e-mail.html.** This newsletter updates what contract awards have been given for that day or the previous day. This information can also be found on the Web at **www.defenselink.mil/news/contracts.html.**

To keep up-to-date on news about the DoD, go to **www.defenselink.mil**. This is the home page for a number of DoD-related links and information such about such things as the defense budget, budget guidance and news about the war on terrorism and other DoD activities.

Another avenue is to work with the various DoD research and development (R&D) organizations. Each service has prime locations that are involved in developing advanced communications and other electronic systems. An overview of some of these centers include:

U.S. Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH (**www.afrl.af.mil**) – AFRL is involved in just about everything from electronics to airframes. It's mission: "Leading the discovery, development and integration of affordable warfighting technologies for our aerospace forces."

U.S Army Research Laboratory (ARL), Adelphi, MD (**www.arl.army.mil**) – ARL's Collaborative Technology Alliance programs looks to team with industry to develop new capabilities. Prime among its efforts is advanced communications.

U.S. Navy Office of Naval Research (ONR), Arlington, VA (**www.onr.navy.mil**) – ONR's focus is to develop technologies such as sensors, surveillance, robotics and other electronic systems. According to the ONR, they were responsible for the development of a number of commonly used technologies from the laser to the Global Positioning System (GPS).

These are the primary research and development centers, but within each are a number of other centers. Start with these three and you can target a specific R&D focus.

—Roger Lesser

Encryption algorithms — thwarting the eavesdropper with secure communications

How public key agreement algorithms can block the human "impairment" in military communications.

By Louis Litwin, Sachin Mody

In digital communications, designers often use algorithms to handle various types of channel impairments. These impairments include phenomena such as multipath channels, thermal noise, Doppler shifts and so on. However, another type of "impairment" exists in a communications system: the eavesdropper.

Unlike natural impairments such as thermal noise, the eavesdropper is a human "impairment." The eavesdropper listens to communications signals with a malicious intent. Most communications system users would prefer that their signal only be received by the intended recipient(s) — especially when the signal carries sensitive information such as military plans, credit card numbers or love letters. Various techniques are used to prevent eavesdroppers from gaining access to transmitted information. Cryptography deals with these techniques to securely convey information.

In a cryptographic system, the original messages or data are called plain text. The plain text is secured by modifying its content with a mathematical algorithm known as a cipher. The cipher is said to encrypt the plain text, and the resulting output is referred to as cipher text. The cipher text is a secured version of the original plain text and can be transmitted openly across a communications channel. Ideally, because of the encryption operation of the cipher, eavesdroppers who obtain access to the cipher text will be unable to uncover the original plain text from the cipher text. Thus, the cipher can be thought of as providing mathematical security, as opposed to physical security such as that provided by sending a message via armed couriers. A block diagram of a basic cryptographic system is shown in Figure 1. An important element of a cryptographic system is the value known as a key.

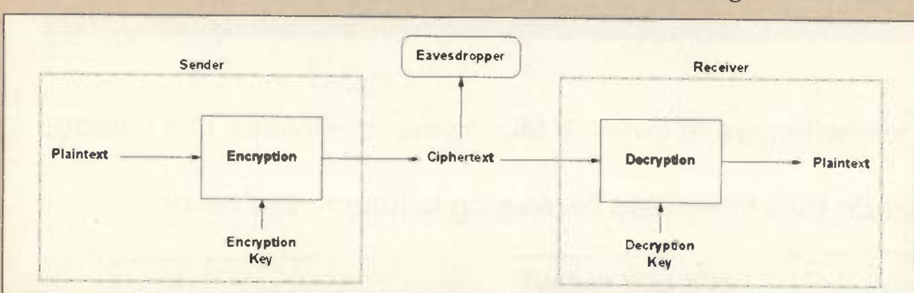


Figure 1. A block diagram of a cryptographic system.

Cryptographic keys

In cryptography, the key serves as a seed for the cipher algorithm. A simple cipher, for example, is the Caesar Cipher. This cipher forms the cipher text by replacing each letter in the plain text by the letter three positions to the right in the alphabet modulo 26. Thus, the plain text letter A becomes D, B becomes E, and Z becomes C. In this example, the algorithm for the cipher is a substitution of another letter in the alphabet. The key value is K = 3, which tells the algorithm to substitute the letter three positions to the right.

In almost all modern cryptographic systems, the security of the system lies in the key, and not in the knowledge of the cipher. That is, it is assumed that the algorithmic details of the cipher are public knowledge. It is better to be safe by assuming this because it is hard to keep an algorithm secret — especially if it is being implemented in a standard. More importantly, one of the best ways to test the security of a cipher is to publish the algorithm in the open literature. Such action leads to an open discussion of the cipher and can expose the algorithm's true weaknesses.

Because the security of the system lies in the key, it is important to keep the key value secret so that only the sender and intended recipients of the message have knowledge of the key. Even if the actual value of the key is kept secret, security can be broken if the eavesdropper tries to decrypt the cipher text using different key values in a trial-and-error process. If only a few possible values exist, such a process could quickly uncover the key value, allowing the eavesdropper full access to the plain text. The set of all possible key values is called the keyspace, and increasing the size of the keyspace increases the security of the system because an eavesdropper has more possible key values to try.

If two people want to have a secure communication, they can meet beforehand and choose a key value. A more interesting problem is posed when two parties, who may have never met, want to have a secure communication. In this situation, the parties need to agree on a secret key value. However, the communications involved in this agreement must be sent unencrypted. These communications cannot yet be encrypted because they don't have a common key that can be used for such encryption. One algorithm that addresses the problem of publicly agreeing on a secret key value is the Diffie-Hellman Public Key Agreement algorithm. Before describing the algorithm, some background will be provided on the mathematics of finite field algebra.

Finite field algebra

Finite field algebra and modular arithmetic deal with modular operations, which restrict all the results to map into a finite field. A finite field is a collection of a unique finite number of elements. Any mathematical operation performed on these elements (e.g., multiplication) will result in a quantity that is also an element in the finite field. The three most basic properties of modular arithmetic are:

$[(a \bmod n) + (b \bmod n)] \bmod n = (a + b) \bmod n$; $[(a \bmod n) - (b \bmod n)] \bmod n = (a - b) \bmod n$; $[(a \bmod n) \bullet (b \bmod n)] \bmod n = (a \bullet b) \bmod n$

The third property can be extended to apply to exponentials by splitting the powers into multiplications. For example:

$11^5 \bmod 13 = (11^2 \bullet 11^2 \bullet 11) \bmod 13.$

Therefore,

$11^2 \bmod 13 = 121 \bmod 13 = 4 \bmod 13.$
$11^4 \bmod 13 = 16 \bmod 13 = 3 \bmod 13.$
$11^5 \bmod 13 = (3 \bullet 11) \bmod 13 = 7 \bmod 13 = 7.$

This example demonstrates that even large exponentials can be broken down into simple multiplications. Also, the modulo of the exponential can be found, but determining the exponent from the result of the exponentiation in a finite field (i.e., a logarithm) is difficult.

Modular arithmetic with prime numbers introduces the concept of a primitive or a prime root. From Euler's equation, the powers of an integer mod n, where n is a prime number, can be expressed as:

$$a^m \equiv 1 \bmod n$$

This means that for any given integer a, an integer m can be found that satisfies this relationship. One condition must be satisfied for this relationship to hold: a and n should be relatively prime (i.e., they don't have any common divisors, or the greatest common divisor for the pair is 1). If n is a prime, then all numbers less than n satisfy this condition.

Here, m is called the order of the integer $a \bmod n$, or the length of the period generated by a. If the length of the period generated by any integer for a given prime number n is $(n - 1)$, then that integer is called the prime root or the primitive of that prime number. In other words, for a primitive root, $a^m \equiv 1 \bmod n$ is satisfied such that $m = (n - 1)$.

	$a^1 \bmod 7$	$a^2 \bmod 7$	$a^3 \bmod 7$	$a^4 \bmod 7$	$a^5 \bmod 7$	$a^6 \bmod 7$
a = 2	2	4	1	2	4	1
a = 3	3	2	6	4	5	1

Table 1. Example of prime number series.

For example, for the prime number $n = 7$, the powers of $a = 2$ and $a = 3$ generate the following series shown in Table 1.

It can be seen from the table that the powers of 3 mod 7 generate the series of all numbers from 1 to (7 – 1), so 3 is a primitive root of 7. The powers of 2 generate a series of only three numbers: 2, 4, and 1. So, the order of 2 mod 7 is 3. Therefore, it is not a primitive.

The primitive root of a given prime number will generate (via powers) a sequence of all numbers from 1 to $(n - 1)$ in some permutation. The length of the sequence that any integer generates is the finite field of that integer for the given prime number. The importance of this result is that any powers of that integer modulo of the given prime number will map into the generated finite field only.

The inverse of this equation is also true. This means that if, instead of finding the exponential, one were to find the inverse or discrete logarithm of it, then all the possible values would also lie in the same finite field. Hence, given an equation of the form:

$$b \equiv a^i \bmod p$$

where p is prime and a is a primitive of p, then all possible values of i that satisfy the equation should lie in the finite field generated by the powers of $a \bmod p$, which is the entire field 1 to $(p - 1)$.

Hence, for the equation:

$$Y = g^x \bmod n$$

The possible values of x that satisfy the equation can be any integer from the set 1 to $(n - 1)$.

The Diffie-Hellman algorithm depends on the difficulty of calculating this discrete logarithm, i.e. finding x from the above equation, for its effectiveness — even when all the other values are known.

The Diffie-Hellman algorithm

The Diffie-Hellman algorithm was invented by Whitfield Diffie and Martin Hellman in 1976. The algorithm allows two parties to publicly exchange information to agree on the value of a secret shared key. This secret shared key k can then be used by both parties as the key to a cipher. Because both parties will have the same value for k, they can encrypt and decrypt messages from each other.

The security of the algorithm is a result of the fact that it is easy to perform exponentiation in a finite field, but difficult to compute logarithms on a finite field. This can be illustrated by example. First, look at the case of regular logarithms (i.e., not on a finite field). As shown in the top part of Figure 2, regular exponentiation is a monotonic operation. For example, if the powers are monotonically increasing, such as 2 < 3 < 4, then a number raised to those powers will result in a monotonically increasing series such as 22 < 23 < 24, or 4 < 8 < 16. However, exponents in finite fields do not exhibit this monotonic behavior, as shown in the

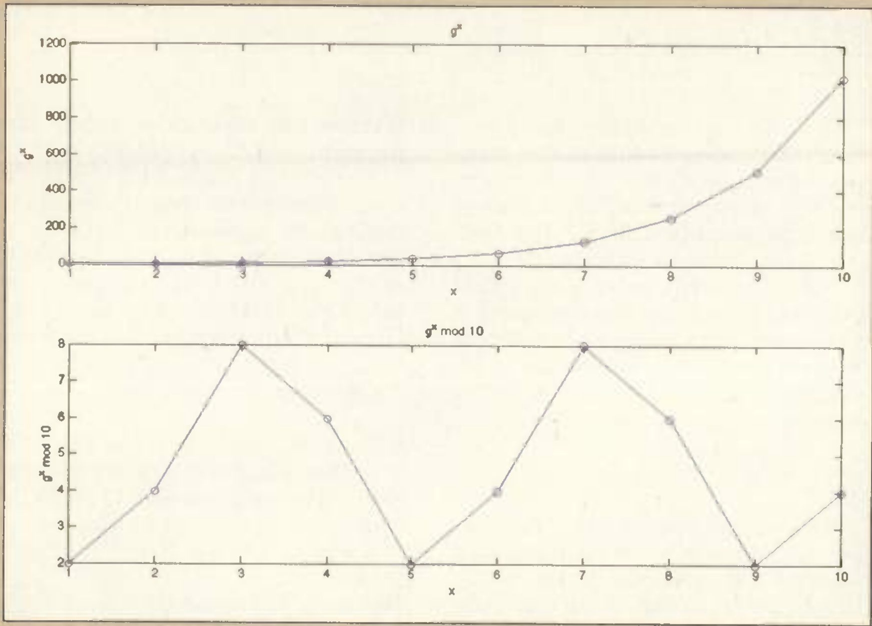


Figure 2: Comparison of regular exponentiation (top) vs. non-monotonic exponentiation in a finite field (bottom).

bottom part of Figure 2.

This non-monotonic nature of exponents in finite fields means that, given $g^x \ mod \ n$, it is difficult to determine x. The security of the Diffie-Hellman scheme is a direct result of this fact.

The Diffie-Hellman algorithm uses three types of keys:

• *Private keys*

Private keys are known only to a given user and are never made available to anyone else. However, the private key is used to create a public key.

• *Public keys*

Public keys can be publicly disclosed. Public keys are often posted on Web sites or appended to e-mail messages. Security is not compromised by revealing the public key.

• *Secret shared key*

The secret shared key is the key that is actually used for encrypting and decrypting messages between the two parties. This key is formed by combining information from both the public and private keys.

Bob, Eric and Alice

This algorithm works as follows. Assume there are two parties, Alice and Bob, who wish to communicate. Alice and Bob first agree on two numbers, g and n. The generator, g, is a number that is primitive *mod n*. The value for g is typically a single-digit number. The value n determines the size of the finite field and it should be a large number. The value for n should be prime, and the value for g should also be prime. These numbers can be made public without compromising security. Next, Alice and Bob select large random integers. These numbers represent their private keys and the values must not be disclosed. Alice's private key will be denoted as x and Bob's private key as y. Alice and Bob then compute their public keys from their private keys. Alice's public key is $X = g^x \ mod \ n$ and Bob's public key is $Y = g^y \ mod \ n$. The public keys are openly transmitted to the other party. Alice and Bob take the opposite party's public key and raise it to the power of their private key. In doing so, both Alice and Bob arrive at the same value for secret shared key k. That is,

Alice computes:

$k = Y^x \ mod \ n$
$= (g^y)^x \ mod \ n$
$= g^{yx} \ mod \ n$

Similarly, Bob computes:

$k = X^y \ mod \ n$
$= (g^x)^y \ mod \ n$
$= g^{xy} \ mod \ n$

Note that the values computed by both parties are identical. Therefore, Alice and Bob can use the secret shared key, k, to encrypt and decrypt messages between each other. The Diffie-Hellman algorithm is not a cipher and it does not do any encryption itself. Instead, the algorithm allows two parties to agree on a key that will then be used with a cipher. The procedure for the algorithm is summarized in Figure 3.

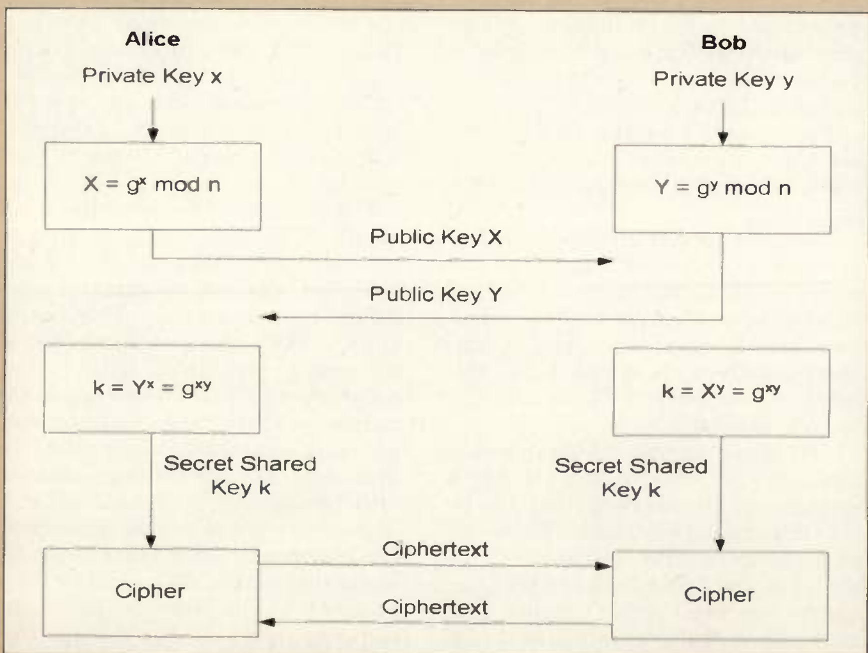


Figure 3: Flow of information in Diffie-Hellman algorithm.

The Diffie-Hellman math

The following example will illustrate how the Diffie-Hellman algorithm works. Note that the numbers are kept small because the values are for illustrative purposes only. Assume that Alice and Bob choose $g = 6$ and $n = 11$. Alice selects her private key to be $x = 3$ and Bob selects his private key to be $y = 4$.

Alice computes her public key as:

$X = g^x \ mod \ n$

$= 6^3 \bmod 11$
$= 216 \bmod 11$
$X = 7$

Bob computes his public key as:
$Y = g^y \bmod n$
$= 6^4 \bmod 11$
$= 1296 \bmod 11$
$Y = 9$

These values for the public keys are openly exchanged. By using Bob's public key, Alice computes the secret shared key as
$k = Y^x \bmod n$
$= 9^3 \bmod 11$
$= 729 \bmod 11$
$k = 3$

Similarly, Bob computes the secret shared key as:
$k = X^y \bmod n$
$= 7^4 \bmod 11$
$= 2401 \bmod 11$
$k = 3$

Note that the key value arrived at by both parties is identical (both determined k to be equal to 3). This value would then be used as the key for a cipher that would encrypt the rest of their transmissions.

Algorithm parameters

This section will examine the different parameters (g, n, x, and y) of the Diffie-Hellman algorithm and will discuss how the values of these parameters can affect the security of the algorithm.

Generator g: The generator value g needs to be a primitive *mod n*. This condition is important because it affects the distribution of possible values in the keyspace. If g is a primitive, then all values in the keyspace are equally probable. However, if g is not a primitive, then only values that lie in a subset of the keyspace are possible. Because g and n are publicly available, an eavesdropper can exploit this weakness to attack the system. An example of this situation is shown in Figure 4. The finite field size is $n = 19$. The plots show histograms formed by $g^x \bmod n$ where $x = 1...18$. The top plot used a generator value of $g = 2$ and the bottom plot used a value of $g = 3$. Although $g = 2$ is primitive *mod* 19, $g = 3$ is not. Note the difference that occurs in the key distribution when a non-primitive is used. The top plot shows that any key value is possible when g is a primitive.

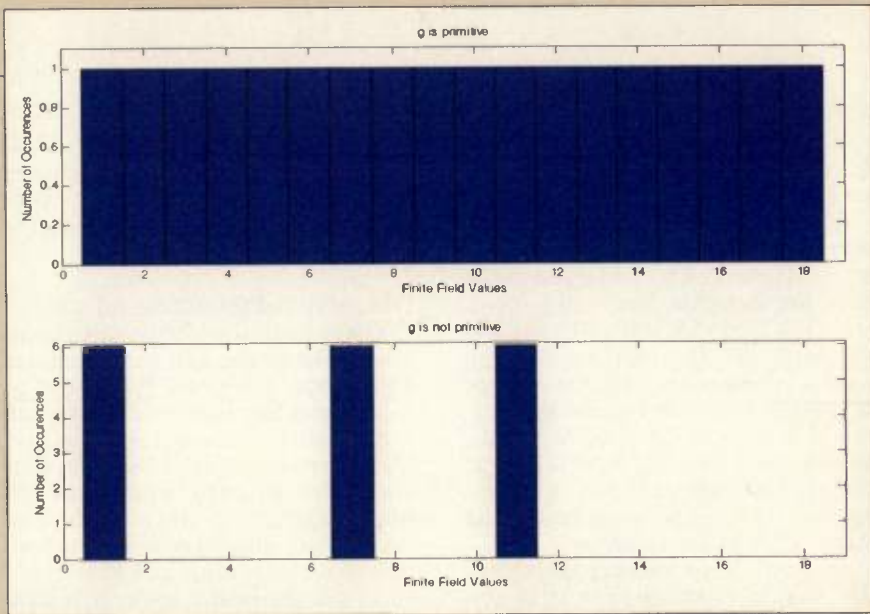


Figure 4: Histograms of key space for $n = 19$. Top plot is for $g = 2$ (primitive *mod* 19) and bottom plot is for $g = 7$ (not primitive *mod* 19).

To compromise security, an eavesdropper would have to try using every key value in the keyspace. That is, he would take the cipher text and try to decrypt it using the first key, then the second key, and so on until a meaningful decrypted output was found (corresponding to finding the correct key). In this simple example, the eavesdropper would have to try, in the worst case, all 18 possible key values.

However, when g is not primitive, only a few of the key values can occur. For the case of $g = 3$ and $n = 19$, the only possible key values are 1, 7, and 11. Knowledge of this sparse keyspace could be exploited by an eavesdropper to greatly reduce the number of keys that he would need to try to break the system.

In this simple example with small numbers, the number of keys that would need to be tried reduces from 18 to 3, an 83.33% reduction. This reduction can be significant when dealing with practical sizes of the keyspace. Typical values for g are single-digit numbers (1...9).

Finite field size *n*

The size of the finite field should satisfy two conditions. First, the value

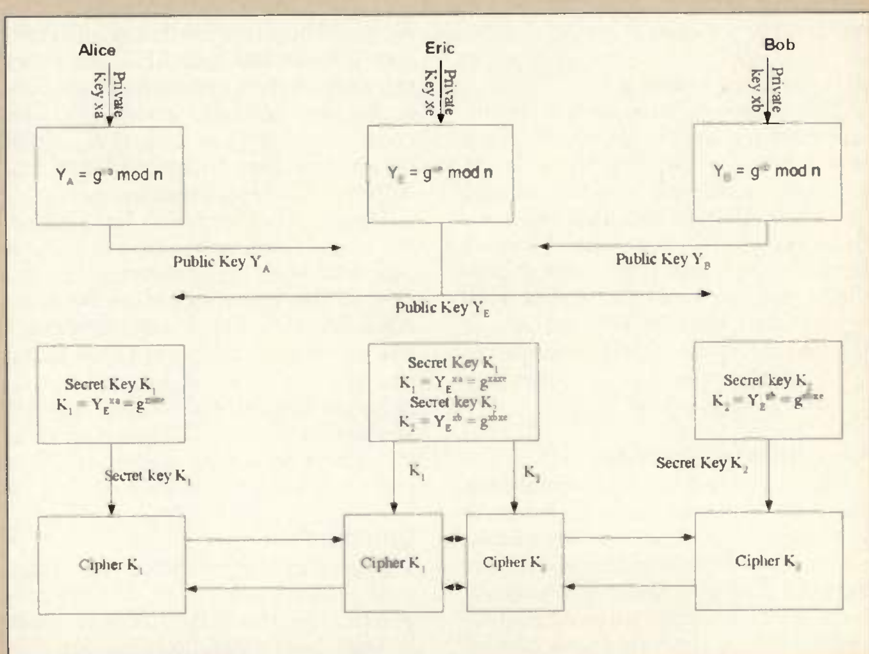


Figure 5: Man-in-the-middle attack.

n should be prime. Second, the value *g* should also be prime (this condition makes *n* a Sophie-Germain prime). If these conditions are not met, the number of possible keys in a field of size, *n*, is reduced by the largest factor of *n*. For example, if $n = 18$ is used, the finite field should have 18 possible values: 0...17. However, because the factors of 18 are 3 • 3 • 2, the number of possible values is reduced by a factor of 3 down to six possible values. Because the largest factor of *n* is 3, the eavesdropper only has to try 1/3 as many keys as he would have if the value of *n* was chosen properly.

In addition to meeting these conditions, it is important that the value of *n* be large. Because all computations are performed on a finite field of size, *n*, the final value of the secret shared key must lie in this field as well. Thus, a brute-force attack by an eavesdropper would be to try every possible value in the finite field. If *n* is small, this task becomes much easier.

As an extreme example, suppose that $n = 4$. Regardless of the values of the other parameters, the secret shared key *k* can only take on 3 possible values. All of these values could be quickly tried and the security would be compromised. In practice, *n* is typically a 768-, 1,024- or 1,536-bit number. In this case, the number of possible keys could be as large as $2^{1,536}$ and the eavesdropper's job is much more difficult.

Private keys *x* and *y*

The values for the private keys *x* and *y* are not too important. The only real conditions are that they should be chosen randomly and they should be large (though smaller than *n*). Because the secret shared key is formed from *x* and *y*, the most important condition regarding the private keys is that they be kept private. If the eavesdropper obtains knowledge of these keys, there is no longer any security in the system.

Algorithm weaknesses

The main weakness cited against the Diffie-Hellman algorithm is that it is susceptible to a man-in-the-middle attack. This attack stems from the fact that the messages being sent between the two parties is not authenticated.

Therefore, the messages can be intercepted by an eavesdropper and can be changed in a way to let the eavesdropper listen to the rest of the secure communication between the users without having to actually discover the value of the secret shared key.

The man-in-the-middle attack

The man-in-the-middle attack can take place in the following manner. Two users, Alice and Bob, want to negotiate a key agreement using the Diffie-Hellman scheme. An attacker, Eric, is trying to gain access to the communication. Eric can impersonate Bob while talking with Alice and he can impersonate Alice while talking to Bob. This way, both Alice and Bob would end up negotiating keys with Eric instead of with each other. Here's how the sequence of events would flow:

- Once the global parameters '*g*' and '*n*' have been negotiated and are publicly known, Bob sends Alice his public key Y_B.
- Eric intercepts this message and sends Alice his own public key, Y_E, based on his private key, x_E, and the same global parameters. This message is sent in such a way that it appears as if it were sent from Bob's host system.
- Similarly, when Alice sends her public key, Y_A, to Bob, Eric intercepts it and sends his own public key, Y_E, to Bob. Now Eric has the public keys of both Alice and Bob, and both Alice and Bob have Eric's public key.
- Now Bob computes the secret key, K_1, based on Eric's public key and Bob's own private key and Alice computes the secret key, K_2, based on Eric's public key and her own private key. Eric computes both keys, K_1 and K_2, based on his own private key and Bob and Alice's public keys, respectively.

Hence, Alice and Bob have different secret keys and cannot communicate with each other directly. For the rest of the communication between Alice and Bob, Eric always intercepts the messages, decrypts them using the sender's secret key, reads it, encrypts it using the receiver's secret key and sends it to the receiver without them knowing about it. This process is shown in Figure 5.

Conclusions

After a brief introduction to cryptography and the concept of a cryptographic key, the Diffie-Hellman public key agreement algorithm was presented. An example of the algorithm was given to illustrate how two users can use the algorithm to agree on a secret shared key. Next, a discussion of the algorithm parameters was presented, which explained how the values of the parameters affected security. Finally, the way in which the man-in-the-middle attack can be used to compromise the security of the algorithm was shown. This vulnerability to the man-in-the-middle attack can be overcome with refined versions of the Diffie-Hellman algorithm, such as the Oakley Key Determination [4] protocol.

RF

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Products

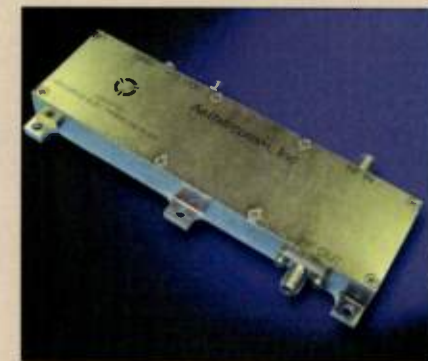
Tactical-grade fiber optic gyro

KVH unveils its new DSP-5000 fiber optic gyro. The gyro accepts data input as fast as 500° per second and offers consistent accuracy over time and temperature. This gyro family is suitable for use in drone and unmanned aerial vehicle navigation, land vehicle navigation, and missile and smart munitions guidance. The device combines KVH's proprietary polarization-maintain-

ing optical fiber and fiber components with integrated digital signal processing. The unit offers outstanding bias stability, low noise, high bandwidth, and scale factor accuracy of 0.05%. It has no moving parts to wear out or require maintenance and provides precise rotational rate information by measuring the phase difference between two paths of light traveling in opposite directions through an optical fiber.
KVH Industries
www.kvh.com

Broadband, multiapplication power amplifier

Aethercomm has designed the SSPA 4.7-19.0-1. The device is a broadband, medium-power, solid-state power amplifier that operates from 4.7 GHz to 19.0 GHz. This PA is suitable for electronic warfare systems, test equipment, laboratory use or anywhere where broadband, high gain, moderate linearity and medium power are required. Minimum gain from 4.7 to 19.0 GHz is typically 37 dB. The minimum P1dB from 4.7 to 19.0 GHz is 30 dBm. The typical saturated output power across the band is 32 dBm. Input VSWR across the band is 2.0:1 maximum. Output VSWR is 2.5:1 maximum across the band. This SSPA operates from +12



VDC with a quiescent current of 1.56 amps. Standard features include overvoltage protection, reverse polarity protection and output open/short-circuit protection. This unit contains a fully integrated DC-DC converter and comes in a modular housing.
Aethercomm
www.aethercomm.com

High-speed, performance spectrum analyzers

Agilent Technologies introduces two members of its PSA family that provide engineers in aerospace/defense, emerging communications and cellular communications speed, accuracy, dynamic range and sensitivity for measuring complex RF, microwave and millimeter wave signals. The E4446A offers code compatibility with 8566 and 8568 modes

to protect the original investment and makes the new products an alternative to updating legacy systems. The E4448A enables users to design and test integrated systems and perform depot-level testing at frequencies as high as 50 GHz. It features an intuitive interface and one-button measurement.
Agilent Technologies
www.agilent.com

Side-launch 75Ω BNC bulkhead jack

Trompeter announces the UCB-BJE20, a PCB-mounted, side-launch bulkhead BNC jack. The jack is designed for true 75Ω performance and carrier-class applications. It offers signal launch geometry for managing the microstrip to coax signal transition between the board and

cable for applications that demand high data rates, high bandwidths and/or high frequencies, with low return loss. It offers a lower profile than standard right-angle jacks. A bulkhead feature allows torque of the BNC coupling mechanism to be transferred to a panel front in lieu of the board. The jack is plated with a thin gold final finish for tight solderability characteristics and a high conductive path. Current designs accommodate board thicknesses of 0.031 and 0.062 inches.
Trompeter
www.trompeter.com

Programmable, dual-output synthesizer

Narda introduces high-performance microwave synthesizers for wireless communications systems, satcom converters, digital radio and optical networks. By using this PLDRO as the low-noise internal oscillator and adding a programmable upconverter circuitry around it, Narda has achieved tunable microwave synthesizers with minimal performance degradation. Features of Narda's new frequency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synthesizers include: low phase noise (typically –92 dBc/ Hz at 10 kHz offset for a carrier frequency of 19 GHz and a step size of 5 MHz); high immunity to shock, vibration, and phase hits; SMT construction; and low DC power consumption. They are available in single or independent, externally-controllable, dual-output configurations.
Narda
www.cell-guard.com

Low-jitter military oscillators

Rakon has added an 18 x 11.7 mm SMD temperature-compensated crystal oscillator (TCXO) to its family of high-performance crystals and oscillators. The TXO500 is designed for military, aerospace and industrial applications. It features temperature stability, performance of sub

ppm stability, and G-sensitivity of less than 0.2 ppb/G. This TCXO also features low hysteresis of ±0.4 ppm, low power consumption of 2.0 mA, and excellent phase noise under vibration performance with a typical value of –120 dBc/Hz at 100Hz offset. Custom frequencies range from 8.2 MHz to 32 MHz with a clipped sinewave output, and are able to operate over the industrial temperature range of –40 to +85° C.
Rakon
www.rakon.com

Expanded line of PICO couplers/hybrids available

Merrimac announces its expanded Multi-Mix PICO Z-Series line of couplers/hybrids and introduces four new directional couplers and two quadrature hybrids for 802.11a (5.5 GHz) and 802.11b (2.4 GHz) WLAN applications. The 2.4 GHz and 5.5 GHz WLAN products bring the total number of Multi-Mix PICOTM products to 16.
Merrimac
www.merrimacind.com

3 and 5 VDC HBT PAs for UNII, HiperLAN

Hittite introduces an efficient family of HBT MMIC PAs, operating between 4.4 and 7.0 GHz with as much as +29 dBm output power. These amplifiers are suitable for UNII and HiperLAN applications from 5.0 to 6.0 GHz. The HMC415LP3 provides 20 dB of gain and +26 dBm of saturated power at 34% PAE from a +3.0 VDC supply

over 4.4 to 6.0 GHz. The HMC406MS8G provides 18 dB of gain and +29 dBm of saturated power at 38% PAE from a +5.0 VDC supply over the 5.0 to 6.0 GHz range. The HMC407MS8G provides 15 dB of gain and +29 dBm of saturated power at 28% PAE from a +5.0 V supply from 5.0 to 7.0 GHz. In each PA, a power-down control input (V_{pd}) can be used for RF output power/current control.
Hittite
www.hittite.com

Mini-hybrid, digitally tunable bandpass filter

Pole/Zero introduces the mini-hybrid, digitally tunable bandpass filter, based on Pole/Zero's mini-pole and maxi/power-hybrid technology. Frequency coverage starts at 108 MHz and the design supports frequency coverage approaching an octave, with as many as 251 tune positions. Although tuning range can approach a full octave for relatively wide bandwidth filters, insertion loss is typically improved as the tuning range is reduced. The filter requires +5 VDC for logic and PIN diode forward biasing, and +10 to 28 VDC for PIN diode reverse bias. The unit is housed in a rugged Mini-PC package, and provides bandpass filtering in both directions (bi-directional).
Pole/Zero
www.polezero.com

RAD shielding for electronic components

Maxwell Technologies has announced the introduction of Xray-Pak radiation mitigation technology to shield integrated circuits that process and store data in military satellites from the radiation effects of nuclear blasts. Xray-Pak integrates flexible, lightweight, metal packaging with proprietary Rad-Pak shielding technology to protect commercial microelectronic components, such as monolithic and multi-chip data converters, memory and logic devices, from Xray emissions produced by the detonation of nuclear weapons
Maxwell Technologies
www.maxwell.com

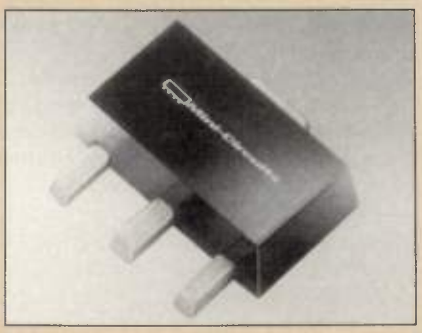
High-density cable assemblies

Tensolite presents a series of high-density shielded interconnects. They consist of low-profile, micro-miniature, ribbonized coax cable and differential pair assemblies featuring Tyco Electronics' MICTOR and Samtec's QTE and QSE coaxial and differential series connectors. These low-profile, high-density assemblies offer optimal signal integrity, achieved through matched imped-

ance cable assemblies. Tensolite assemblies are built to order, with a customer-specified number of signal lines and overall assembly length.
Tensolite
www.tensolite.com

DC to 4 GHz MMIC amplifier

Mini-Circuits announces the Gali-55, a newly developed MMIC amplifier for DC to 4 GHz that is usable to 6 GHz. When operated at



2 GHz/25°C, the unit delivers 18.5 dB gain (±1.7 dB typ flat DC to 2 GHz), maximum output power of 15.0 dBm (typ, at 1 dB comp.), and high 28.5 dBm (typ) 1P3. These 50Ω amplifiers are housed in a small SOT-89 package with exposed metal bottom for heat dissipation. The device displays low 100° C/W (typ,ϕjc) thermal resistance.
Mini-Circuits
www.minicircuits.com

Radar test system with repeatability and accuracy

Anristu debuts the ME7220A, Radar test system, which uses innovative design techniques to create a price and performance breakthrough in testing mm-wave mobile radar. The system is designed for characterizing current and future generations of mobile radar, including adaptive cruise control (ACC) and collision warning or avoidance radar. It combines target simulation and signal analysis capability in one instrument. It offers better accuracy, occupies significantly less space, and is easier to operate than rack-and-stack systems. Designed for use in a confined and controlled environment, it provides a simulated radar target response with an adjustable radar cross section and one of two set target ranges. The signal response can be Doppler-shifted to simulate the speed of a moving target. It can simulate a 120-meter target moving at speeds as high as 250 km/h, with less than 2-meter, 10.2-km/h accuracy. The ME7220A can also change the size of the target by 50 dB.
Anritsu
www.us.anritsu.com

VNA test cables as high as 50 GHz

MegaPhase announces Groove-Tube VNA test cables for OEM products through 50 GHz. The new series

is a highly flexible, armored test cable used in demanding lab or production environments where exceptional phase and amplitude performance are necessary. The MegaPhase VN Series offers a viable alternative for test engineers. Its phase and amplitude change vs. flexure is typically <12° and <0.13 dB through 50 GHz; through 18 GHz typically <3° and <0.04 dB with excellent recovery. Standard connectors include 2.4 mm, 2.92 mm, 7 mm, 3.5 mm, SMA, Type N and "ruggedized" female port connectors, available for direct interface to instrumentation ports.
MegaPhase
www.MegaPhase.com

350 mW Raman pump Laser

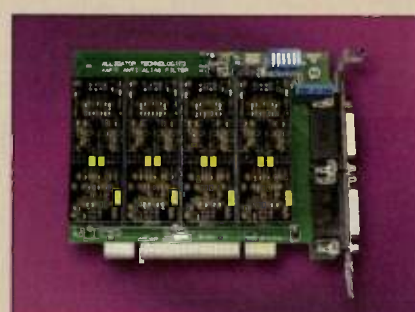
Corning introduces the Optilock VR2e, a Raman pump laser with operating power as high as 350 mW. This product offers the highest power available in a standard 14-pin butterfly package. The Optilock VR2e can be used to replace a two-pump subsystem with a single pump, offering greater levels of simplification, along with the associated cost reduction. By combining proprietary chip design and a unique chip material system with efficient packaging technology, the Lasar provides inherently high optical and electrical efficiency. When used in a conventional system, that polarization multiplexes two pumps per wavelength. This enables more than 500 mW per wavelength.
Corning
www.corning.com

Software for automated analysis of PCBs

Ansoft announces the SIwave signal integrity software. The software enables engineers to model entire PCBs and package structures using a full-wave analysis engine to generate both frequency- and time-domain results. It allows designers to characterize simultaneous switching noise, power and ground bounce, resonances, reflections, and coupling between traces and power/ground planes. Furthermore, engineers can combine their own driver/receiver models with SIwave's SPICE output to obtain accurate SPICE system-level simulations.
Ansoft
www.ansoft.com

Tunable noise-elimination/anti-alias, low-pass filter

Alligator Technologies introduces its latest anti-aliasing, low-pass filter card, the AAF-2. The card is a two- to eight-channel, tunable low-pass filter with selectable frequency ranges in popular Butterworth, Bessel, Cauer or Linear Phase characteristics. It eliminates noise and alias errors while providing DC and gain accuracy for 16-bit data acquisition systems. The filter channels are fully isolated from the PCI bus and continuously tunable in a range from 0.1 Hz to 200 kHz making it suitable for filtering applications in sound and vibration testing, ultrasonics, acoustics, structural analysis, industrial, test, scientific and laboratory



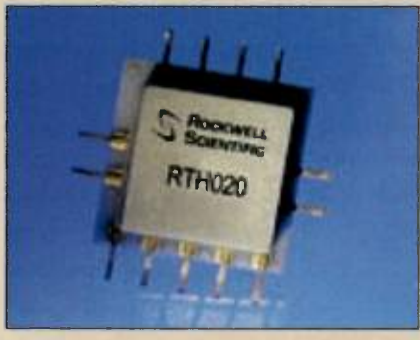
data collection and applied mechanical applications in electronics, aerospace, field research, automotive and process control industries. Its output impedance is less than 0.001Ω, making it compatible to all popular PCI-based or stand-alone A/D converters. Common mode rejection is 90 dB to 110 dB. The Input and output range is up to ± 10 VDC, while gain accuracy is ±0.001 dB at 1kHz.
Alligator Technologies
www.alligatortech.com

Set measures frequency stability of precise oscillators.

Timing Solution's TSC 5110A time interval analyzer automatically compares two continuous-wave RF signals (sinusoidal or square-wave) between 1 and 20 MHz. It measures the real-time phase difference at a 10 ms sample rate and computes the Allan deviation. The instrument has been designed for making fast and precise frequency stability measurements in both R&D and production test environments. Its noise floor (5×10^{-14}, Allan deviation at 5 MHz) and high resolution (100 femtoseconds or 0.1 picoseconds) allow measurement of all precise oscillators, such as Cesium, Rubidium and TCXO (temperature controlled oscillators). In addition, the two RF input signals need not be the same frequency. This feature eliminates the need to maintain multiple frequency standards; instead just one house standard is needed for all measurements.
Timing Solutions
www.timing.com

Dual T/H chip for ultra-wideband data acquisition

Rockwell introduces a 10 GHz bandwidth 1 GS/s dual track and hold (T/H) circuit for ultra-wideband data acquisition. Designed for direct sampling of multi-gigahertz signals, the bandwidth is 9 GHz for 0.5 Vpp inputs and more than 10 GHz for small signals. The master-slave configuration of this dual T/H device holds the output signal for nearly an entire clock cycle, significantly easing the bandwidth requirements for subsequent circuitry, such as ADCs. With under 1 mV noise and less than 100 fs aperture jitter, it achieves a 56 dB signal-to-noise ratio and a –63 dB total harmonic distortion for a 500 MHz input signal at a full-scale power of



1 V_{pp}. Used in conjunction with existing ADCs, the T/H eliminates mixer and filter functions, lowering system cost by bringing the ADC closer to the antenna.
Rockwell Scientific
www.rockwellscientific.com

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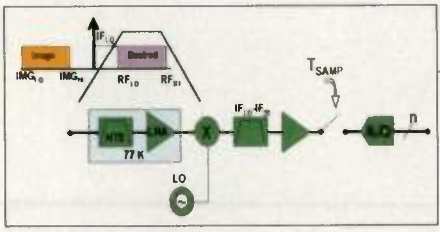

Figure 13. Single conversion digital radio block diagram.

the components downstream, and particularly the A/D converter.

For A/D conversion, there is typically a trade-off between the sampling rate (which in turn determines the maximum bandwidth that can be processed) and the resolution. To digitize a cellular band assigned to a service provider, the A/D converter ideally should be able to process 20 MHz of RF bandwidth, which implies a sample rate of at least 40 MHz, and typically 45 MHz to 50 MHz. At these high sampling rates, high A/D resolutions are difficult to achieve without resorting to more complex conversion schemes.

By cryogenically cooling additional components, such as the LO oscillator and the A/D converter, better performance can be achieved. Cooling the LO can lead to lower phase-noise, which improves blocking performance. Cooling the A/D converter can provide means to higher resolution A/D conversion, as well as faster sampling throughput.

Conclusion

In a little more than 10 years, HTS made its way from discovery in 1987 to first-generation production-level products. As HTS becomes more recognized, it will find additional applications. Further research will yield even higher resonator Qs, higher power handling and innovative ways to integrate HTS with larger systems. **RF**

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About the author

David R. Chase is Vice President of Systems Technology. He is responsible for strategic product direction and wireless technology business development at Superconductor Technologies. He has developed a broad range of wireless and wire-line communications systems, holds two issued patents with several pending, and has authored a number of articles on communications system architecture, design, applications and optimization. He obtained undergraduate and graduate degrees in Electrical Engineering from University of California, Santa Barbara. He can be reached at *dchase@suptech.com*

Wireless broadband – coming of age

After many false starts and much hype, the building blocks of broadband's future are falling into place.

By Ernest Worthman

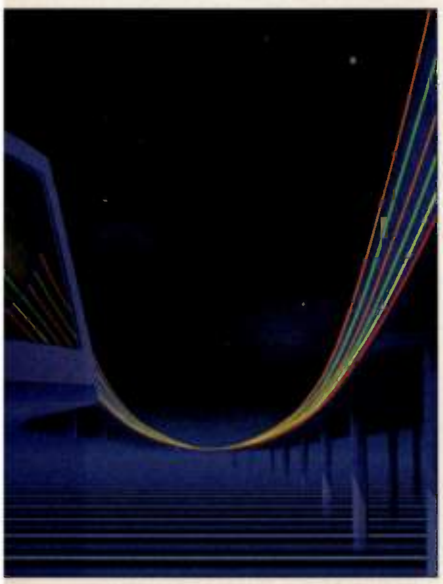
You're likely to hear the term broadband just about anywhere. From satellite broadband to fixed wireless broadband to high-definition television (HDTV), broadband often means different things to different people.

While broadband can have different meanings, the bottom line is that broadband basically refers to a lot of bandwidth, regardless of application or delivery system. There is no defined minimum or maximum bandwidth and there is no specific frequency at which broadband exists exclusively.

Broadband — the hype

Much of what is referred to in the consumer industry as broadband is simply good guerrilla marketing – using the term to define a product.

Because broadband refers to a wide bandwidth, it in turn implies the ability to run bandwidth-hogging applications such as real-time multimedia and high frame-rate video.



Broadband merges onto the information super highway.

While theoretically this is true, broad bandwidth is subjective. To some, broadband can be a few hundred kilohertz, while others consider broadband gigahertz. There is a lot more involved in sending data over a fairly wide bandwidth than the marketers want the consumer to know.

Issues such as compression, two-way transmission capability and power, just to name a few, are all relative factors in the quality and loading of broadband systems. And, distribution networks have to be worked out, as well as interference and rights-of-way.

However, broadband is pressing ahead, even if the pace is a bit slower than expected. And the different broadband opportunities (satellite, TV, last mile, etc.) are beginning to emerge, each with its own particular flavor.

The types of broadband vary

Broadband wireless can be looked at as having three basic levels – macro, micro and pico. Each has its own particular strengths and weaknesses, based on these criteria: application, bandwidth and coverage area. At the pico level are Bluetooth and wireless local area networks (WLANs). These technologies operate from 1 to 54 Mb/s and they are content-insensitive. They can transmit data, voice and video, and can perform file sharing and remote access within a small (typically 100 to 300 meters) zone. They are unlicensed and generally dynamic and ad-hoc focused.

At the micro level, the typical application is wireless Internet with fixed and mobile Tx/Rx points, as well as a larger coverage area.

At the macro level is cellular data – code-division multiple access (CDMA), typically.

Each has its own particular bandwidth requirements.

A shining star

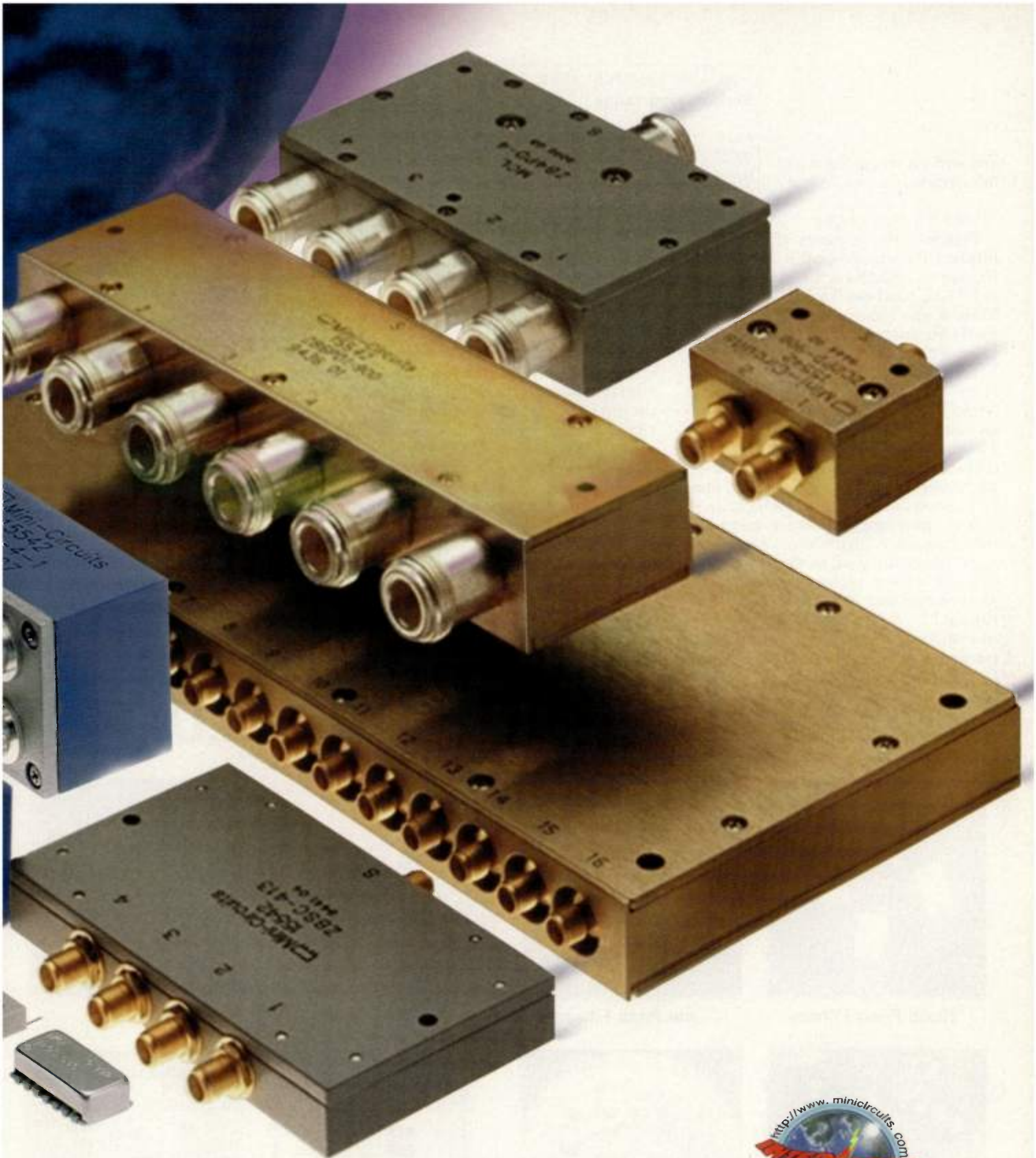
One promising broadband technology showing noteworthy progress at the micro level (at least in planning) is fixed wireless. What makes this so attractive is that a 6 MHz wireless TV channel, using 64-quadrature amplitude modulation (QAM), can support 27 Mb/s of downstream data. This has service providers salivating at the potential to deliver data-intensive multimedia and bandwidth-hogging Internet junk content.

This also has providers looking hard at one particular segment, fixed wireless broadband, as a wireline and cable replacement for the last mile, or wireless local loop — the last leg of the cable route from the distribution box to the home.

The last mile has been a target of opportunity for some time now but has been logistically difficult. To provide similar bandwidth by traditional means requires overhauling the wired infrastructure by upgrading hardware and stringing thousands of additional miles of fiber, coax or twisted-pair wiring — an ugly scenario.

Fixed wireless presents an attractive solution because it has the ability to rapidly introduce high-speed data access, Internet and high-quality digital data, video and voice services throughout a metropolitan area without the time, cost or delay of wired plant upgrades. And, it can do so for more than just the last mile. It is attractive for wireless L/W/M-ANs (M is metropolitan), Internet and fixed and mobile multimedia delivery. Basically, all a wireless operator has to do to be open for business is pick a frequency, and install a head-end and transmission tower.

This particular flavor of wireless broadband is about as perfect a solution as can be envisioned because it has the potential to deliver the much-heralded consumer applications being touted as the driving force behind the next technological revolution



Available spectrum in the 2.1 to 2.7 GHz Band

Service	Freq. range	# of channels	channel width
MDS	2.150 - 2.162 GHz	2	6 MHz
WCS	2.305 - 2.320 GHz	2	5 & 10 MHz
WCS	2.345 - 2.360 GHz	2	5 & 10 MHz
ITFS	2.500 - 2.596 GHz	1	66 MHz
MMDS	2.596 - 2.644 GHz	8	6 MHz
ITFS	2.644 - 2.686 GHz	4	6 MHz
MMDS	2.686 - 2.689 GHz	31	125 KHz

Table 1. Spectrum availability within the 2 GHz band.

and without any of the wired infrastructure issues.

Where it's happening

Presently, the frequency of interest for wireless cable, Internet and WLANs is the 2.1 to 2.7 GHz band (see Table 1). There is also some activity in the 5 GHz and super-high frequency (SHF) range of 27.5 to 29.5 GHz.

The 2 GHz band is the most active due to cost and, to a lesser degree, technology (technology, of course, is becoming less of an issue at today's pace of development). The equipment for the 5 GHz, and especially the SHF band, is a relative issue — the higher the frequency, the less of, and more expensive the equipment becomes.

And, propagation issues increase with frequency. Short-term progress is more likely to occur at the lower frequency where technology is more mature and less expensive (and more robust). Eventually, however, like all technologies, the price/performance/equipment curves of the higher frequencies will flatten.

The services

Delivery systems evolving for the broadband arena include multipoint distribution services, (MDS), multichannel multipoint distribution service (MMDS) and instructional television fixed service (ITFS). There are others in the wings, such as the ultra-high frequency (UHF) TV bands, but politics and current user allocations are slowing progress there. Eventually, however, UHF will give up some of its bandwidth, so look for this to pop dow the road.

Presently, potential fixed wireless providers have aggregated available MDS, MMDS and ITFS spectrum, in a given market, providing as much as 200 MHz of bandwidth. This is the equivalent of 33 analog 6 MHz TV channels. And, from a digital perspective, this is equivalent to 200 Mb/s of raw digital bandwidth.

Fixed wireless' implementation

Whether it is WLANs, the last mile or wireless Internet, fixed wireless is based on line-of-site (LOS) technology (but, that's changing). This can present issues of reliability similar to those of satellite or broadcast TV.

Distance is probably the top design consideration. Wireless cable signals can typically only be received within a 30-mile radius of the transmitter, and that's under optimal conditions.

Impediments to signal path such as dense tree cover, hilly terrain, buildings and heavy precipitation can degrade reception. Multipath distortion (signal reflections off of buildings or other structures) also causes problems. However, because most of these issues have been around for a long time, the industry has a pretty mature database from which to model.

On the other hand, fixed wireless has

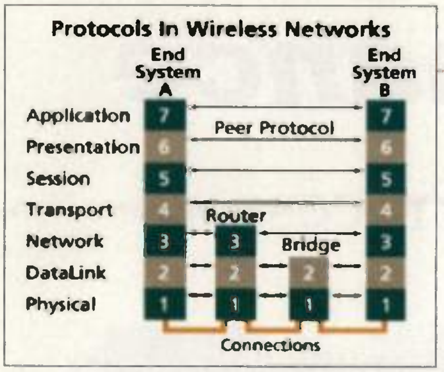


Figure 1. Typical protocol stack for wireless networks.

one obvious advantage. In terms of performance, fixed wireless allows for downstream connections ranging from 500 Kb/s to 155 Mb/s — faster than digital subscriber lines (DSL), cable, or T1 lines. The only significant disadvantage at this point is that the upstream data is much slower. This is because the upstream data is usually sent via a telephone line limited to about 53 kb/s.

This works because today about 80% of Internet traffic is downstream. But that's changing as large files (multimedia in particular) are finding their way upstream as well. Therefore, to accommodate this shift, some wireless channels (particularly the ITFS) are being allocated to become the upstream data port for fixed wireless. This will dramatically improve the uplink data rate and enhance two-way file and image transmissions.

How it's happening

The most prolific applications for potential fixed wireless systems today are for broadband access to the Internet or establishing local/wide/metropolitan-area networks. Basically, the infrastructure is similar for both.

The network infrastructure requires three main ingredients: protocols, interfaces and hardware. Software, in terms of middleware and end user also play a role, but because this article focuses on wireless, those topics will be left for discussion at a later time.

Essentially, the focal point of the wireless access point has become the mobile computer. The lines of distinction have blurred when it comes to using it to link corporate businesses, consumer services or Internet connectivity. All can use fixed wireless in one fashion or another and require much the same wireless infrastructure. As one lowers the level, one starts to see particular technologies or layers used.

One argument for employing fixed broadband is that if the wireless network can use the same networking protocols as the fixed-end network, connections are more streamlined and interface issues become more manageable. Furthermore, standard protocols and routers can be used to interconnect the wireless network to the fixed-end networks (see Figure 1).

The protocols

Wireless links for the above generally use the following protocols. Obviously, there are variations on the protocols, but the platform has to be relatively standard.

Four main layers exist in such networks. The lowest is the physical layer where the RF carrier signal is digitally modulated to create a bit stream. It contains all of the modulation and transmission protocols like forward error correction (FEC), transmission rate determina-

tion, interleaving and other techniques to maximize the data transmission and minimize errors.

Above that sits the link layer. This is where things usually go wrong because it demands the most proprietary and specialized protocol optimized for the radio environment. The process involves link protocols that interact between the wireless modems and base stations. Given the fact that so much equipment already exists, much of which is legacy, coming up with a form of medium access that is acceptable to all is daunting at best.

Layer three is the network layer. Some (not all) wireless WANs, such as macro-level RAM mobile data and ARDIS have been around for a while. This is another area where one finds a fly in the ointment. Inherently, these networks are highly proprietary. The use network-layer protocols designe specifically for that network, so ofte trying to interface to them is anothe daunting challenge. It's not that i can't be done, it's just that the mor interfacing one has to do, the slowe and more complex the system gets.

Fortunately, as of late, and thanks t the Internet, the trend is being force toward Internet protocol (IP) stacks This may be the saving grace for ubiquitous interconnect because, like it or not it has become the defacto standard fo public interconnect protocol. And everyone knows what happens when on tries to buck a widely accepted trend Witness that such is the case with cellular digital packet data (CDPD), as wel as the packet services being develope for personal communications service (PCS) networks (global system fo mobile communications — GSM, CDMA and time-division multiple access – TDMA).

The fourth communal layer is th transport layer. Above this layer ar things like applications, session initialization protocols and other various industry protocols. These layers usuall are not part of the wireless network, bu are implemented as part of the application solution. Some transports have bee designed specifically for wireless networks. But it is also possible to use trie and proven transports such as TCP though some optimization of TCP's timing parameters and algorithms tends t yield better results.

The software interface

Once the protocol is in place, access t the network is necessary. This is accomplished by the interface. Because th interface is largely software, it is onl given a cursory overview.

Interfaces determine access points t the network, both at the mobile and a the fixed-end. At the mobile, the interfaces of interest are between the application and the protocol stack and betwee the mobile and the wireless modem. A the fixed end, the area of interest is th interfaces the wireless network presents.

Determining hardware requirements

Given that the protocol stack and interface are in place, hardware is the final plug-in. Hardware is determined b the above, but does have some variables.

Mobile computers, Internet appliances, personal digital assistants (PDAs), 3G phones and whatever comes

down the line next are all going to have to be wireless, multifrequency, multiprotocol *and* broadband. The biggest issue here will be hardware compatibility. The next generation of wireless devices must be system-agile and protocol-independent — meaning that they must configure on-the-fly and be pay-and-go. End users aren't interested in reading directions or manually configuring wireless devices – the cellular industry taught us that. It will be interesting to see how this issue shakes out.

Wireless broadband's hurdle – LOS

As we are all painfully aware, reliability is the bane of wireless communications and current wireless infrastructures fall short. Assuming the technological and political issues previously discussed are resolved (and, without a doubt, they eventually will be), the last major hurdle to over come is the LOS roadblock.

Ultimately, broadband wireless must provide subscribers with high data rates over non-line-of-sight (NLOS) fading channels at wireline reliability — no insignificant challenge. And the key here is *non-line-of-site*.

NLOS has been addressed in the IEEE 802.16a channel models, which address NLOS characteristics such as Rician K factor and delay spread.

Putting aside the normal technospeak that accompanies such standards or specifications, NLOS is designed to find a way to receive signals based on dynamic conditions (read: addressing fading).

While there are several levels of "near-LOS," let's focus on true NLOS links.

Such links address deep fading. For single-input, single-output channels under NLOS, the random received-signal level is said to be Rayleigh-distributed. Rayleigh-defined links are defined by the 10/10 rule, which states that 10% of the time, a signal is 10 dB below, or effectively one-tenth of its nominal level. That means that, to guarantee that a 10 dB fade can be overcome, the transmit power sent from a transmitter has to be 10 times that of LOS — or, 10 dB margins.

For even better reliability (99%), the Rayleigh statistics tell us that 1% of the time a signal is 20 dB below, or 1/100 of, its nominal level. That means a 1% down time must be accepted, with power cranked to 100X that of LOS. Finally, to ensure 99.9% reliability, a 30 dB power boost (1000X) would be required.

Because this amount of extra power is unworkable, the ideal of spatial diversity is being given serious consideration. This means that, when receiving, a signal is simultaneously sampled and combined at multiple locations in space. Transmitted signals are simultaneously launched out of multiple locations in space. Wow...this looks like it just might work.

Diversity isn't new. But looking at it for broadband wireless is certainly forward thinking. Antenna diversity is a strong contender for a reliable and viable (the IEEE thinks so as well) next-generation wireless broadband infrastructure. To date, wireless broadband has promised much and delivered little. While NLOS issues are paltry when compared to the political and technological issues, they may just be the final crank that starts the engine. If reliability can be used as a marketing tool, the customer might just listen.

RF

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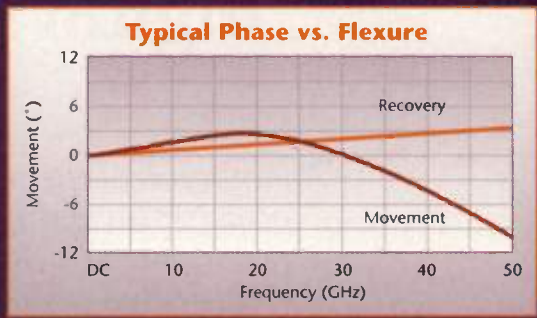

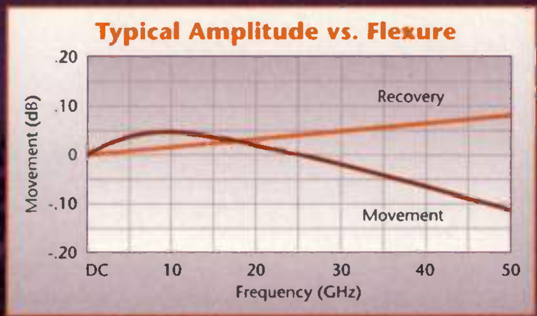

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Output back-off requirements for root-raised, cosine-filtered digital signals

An analysis of the peak-to-average power ratio of different digitally modulated signals when a root-raised cosine filter is used.

By John S. Seybold

In the design of digital communication systems, Nyquist filtering is typically used to limit the required bandwidth of the transmitted signal without producing inter-symbol interference (ISI)[1].

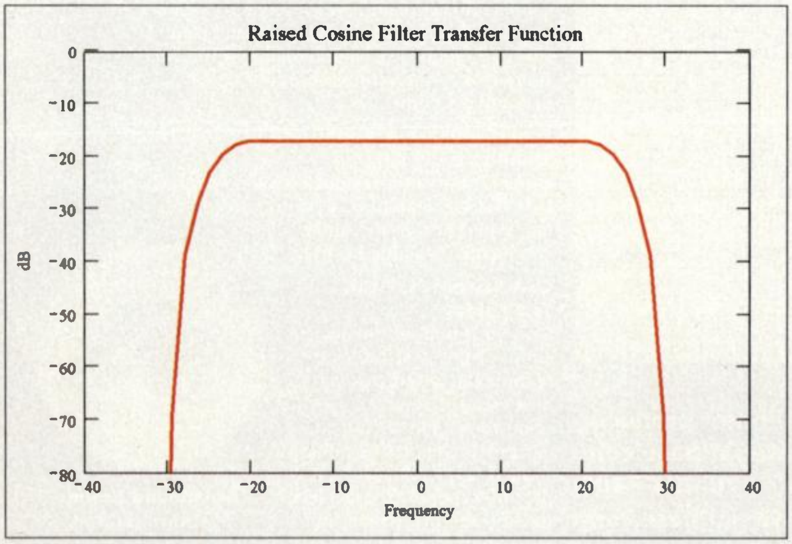

Figure 1a. Raised cosine spectrum, baud = 50, α = 0.2

The raised cosine filter is a common choice because it satisfies the Nyquist filter requirements and is readily implemented. The price paid for the limitation of the bandwidth is an increase in the peak-to-average power ratio of the transmitted signal.

Figures 1a and b show the frequency transfer function of a raised-cosine filter and the associated impulse (time) response. The filter shown is for a baud rate of 50, which may also be interpreted as 50 kbaud or Mbaud. The zero ISI comes from the fact that the impulse response of the filter is always zero at the symbol sample times (as seen in Figure 1 b). Communication theory dictates that the receiver be constructed using a filter that is matched to the transmit signal[2,3]. To achieve this objective, the raised cosine filter can be split between the transmitter and receiver, giving rise to the root raised-cosine (RRC) filter[4].

The frequency transfer function of the RRC filter is the square root of the frequency transfer function of the raised cosine filter. The spectrum of the transmit signal is then equivalent to the RRC filter transfer function because the data stream itself is a sequence of impulses at the baud rate.

Root-raised cosine filtering

Using a root-raised cosine filter (RRC) at both the transmitter and receiver results in a matched filter implementation, thereby maximizing the probability of detection and minimizing the bit error rate (BER).

Figure 2 shows the frequency transfer function and the impulse response of the root-raised cosine filter. Note that the RRC filter is not a Nyquist filter because the nulls of the impulse response do not all fall on the symbol sample times. Only the result of convolving the transmit-and-receive RRC filter responses produces the required Nyquist filter properties.

The RRC filter can be implemented as a correlation receiver using a standard finite impulse response (FIR) digital filter implementation. While there is no closed-form expression for the impulse response coefficients, they are readily obtained by taking sampled values of the frequency transfer function and applying the inverse discrete Fourier transform (IDFT). For an FIR implementation, it is necessary to truncate the impulse response, which is a source of implementation error. The smaller the value of α to be used, the longer the truncated impulse response should be. For this application, a filter of 12 symbol periods was used.

The RRC filter has some interesting and useful properties. One property is that the occupied bandwidth is equal to $(1 + \alpha)$ times the baud rate. For this reason, α is sometimes referred to as the excess bandwidth. Another interesting property is that the noise equivalent bandwidth of the filter is always equal to the baud rate and does not depend

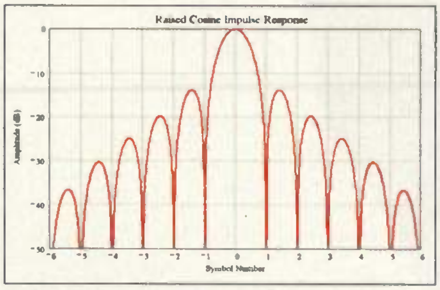

Figure 1b. Raised cosine impulse response, baud = 50, α = 0.2.

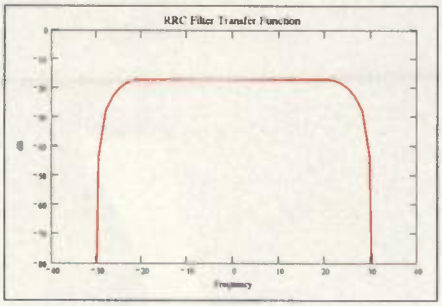

Figure 2 a. Frequency transfer function of the RRC filter, baud = 50, α = 0.2.

on the value of α. Thus, changing the value of α does not change the noise equivalent bandwidth, and thereby does not affect the receiver noise floor. A key factor in the use of the RRC filter is that changing the α of the filter changes the peak-to-average power ratio (PAPR) of the filtered signal. Smaller values of α require less bandwidth but have a greater PAPR.

Peak-to-average power ratio

The PAPR is defined as the ratio of the peak envelope power to the average power. The term crest factor is sometimes used interchangeably with PAPR, but other works have defined the crest factor as the ratio of the maximum signal value to the rms value[5]. This definition produces values that are 3 dB greater than the PAPR as defined herein.

0594+0,0929i
−0.173−0.026i
0.08+0.020i
−0.034−0.012i
$0.011+5.084e^{-3i}$
$8.073e^{-4}+4.838e^{-4i}$
$-5.085e^{-3}-3.770e^{-3i}$

Table 1. Values of the RRC filter coefficients at the midpoints between samples.

Figure 3 shows what a sequence of RRC filtered symbols might look like when superimposed in time. Figure 4 shows what the resulting summation would look like if the symbol sequence was one of the worst possible cases.

This is estimated by adding the absolute values of the all of the filter responses, squaring that sum and then converting to dB. It can be seen that the peak values occur near the midpoint between symbol sample times.

Table 1 shows the values of the impulse response from each filter if the symbols were all ones. This table indicates that the worst possible sequence of symbols is one in which the first five symbols of the sequence alternate by 180° phase. Note that this portion of the analysis is for the RRC filter only and does not include any potential PAPR contribution of the constellations. The effect of the constellation will be considered shortly.

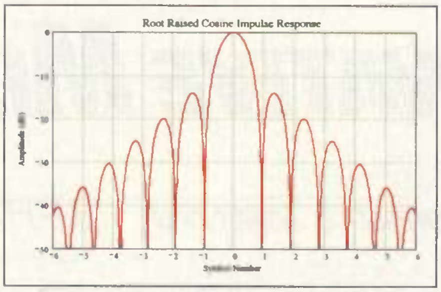

Figure 2b. Impulse response of the RRC filter, baud = 50, α = 0.2.

Often, the argument is made that the probability of a worst-case sequence of symbols occurring is so small as to be negligible. Therefore, the PAPR is not a good predictor of the required output back off[6]. From examining Figure 3, however, one can see that just a few symbols in a row can provide a PAPR that is close to the theoretical worst case.

Figure 5 shows a plot of the PAPR of a RRC filter (with an alpha of 0.2) vs. the number of worst-case symbols in a row. Note that the PAPR approaches the theoretical maximum very quickly. By seven symbols in a row, the PAPR is at 5.4 dB, which is within 0.2 dB of its maximum value for the filter under consideration. Five symbols is within 0.5 dB of the maximum value. If all of the symbols in a constellation are considered equally likely, then it is possible to compute the probability of reaching any given PAPR without having to determine the actual worst-case sequences. The probability of a worst case symbol sequence is given by the following expression:

$$P = \frac{Np}{(2^m)^{Ns}} \qquad (1)$$

where 2^m is the total number of symbols in the constellation, Ns is the number of symbols in the worst-case sequence and Np is the number of symbols in the constellation that have the maximum magnitude. The assumption here is that only a sequence of maximum value symbols with the worst cases phases can produce an inter-symbol peak of concern.

As the level of the PAPR decreases the symbols that are near the maximum value will also begin to contribute to the PAPR. Therefore, this expression provides an order of magnitude estimate rather than a precise calculation of the probability of reaching a particular peak value.

For example, in the case of 16-quadrature amplitude modulated (QAM) signal, only the four corner symbols are of maximum magnitude, so equation (1) becomes:

$$P = \frac{4}{(16)^{Ns}} \qquad (2)$$

Figure 6 shows a plot of probability vs. PAPR for 8-phase shift keying (PSK) signal (which actually applies to any order PSK) and several different orders of QAM . Note that the PAPR values on the X-axis include the PAPR of the constellations, as well as that of the filter.

In addition to the PAPR of the filter the symbol constellation may also contribute to the PAPR. In the case of PSK, the PAPR is unity, so there is no contribution. For QAM modulation the PAPR contribution depends on the order of the modulation. The PAPR of a constellation is computed by assuming each symbol is equally likely. Thus, the PAPR is computed by dividing the magnitude squared of the largest symbol by the average of the square of each of the symbols[7].

Table 2 shows the PAPR of several different constellations expressed in dB. These values are added to the predicted PAPR for a sequence of symbols when using an RRC filter. It is interest-

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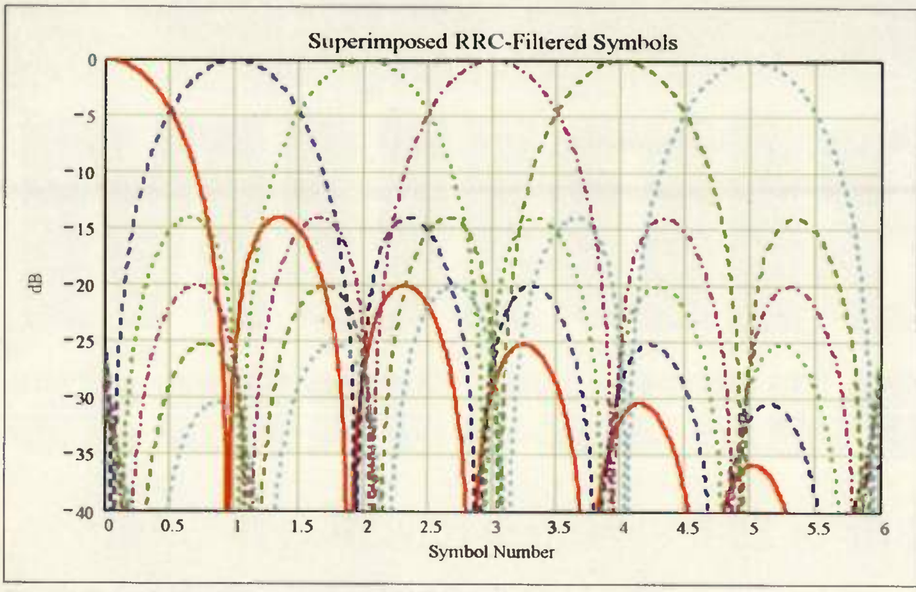

Figure 3. Conceptual plot of a sequence of RRC filtered symbols.

ing to note that the PAPR of 16-QAM is greater than that of 32-QAM. This is because 16-QAM is a square constellation, while the 32-QAM constellation is nearly round.

Modulation	PAPR
N–PSK	0 dB
16-QAM	2.6 dB
32-QAM	2.3 dB
64-QAM	3.7 dB
128-QAM	4.3 dB

Table 2. PAPR of the constellations for different modulation schemes.

Table 3 shows a comparison of the PAPR of the RRC filter for several different values of α. Thus, tables 2 and 3 provide all of the data required for determining the maximum PAPR of a given signal. This is also the theoretical maximum output back-off requirement for a given configuration.

Alpha	PAPR
0.15	6.3 dB
0.2	5.6 dB
0.3	4.5 dB
0.4	3.5 dB
0.5	2.8 dB

Table 3. PAPR of the RRC filter for different α.

Determining required output back-off

As previously mentioned, there is often a desire to limit the amount of output back-off to provide maximum efficiency and transmit power. If the peak values exceed the 1 dB compression point of the transmitter, it will not be faithfully reproduced by the transmitter. This results in inter-symbol interference (ISI).

One way to envision this effect is to allow the power amplifier to go into compression, thereby limiting the inter-symbol peaks. The transmitter is effectively modifying the RRC filter coefficients on the transmit side. When convolved with the RRC filter at the receiver, the two no longer form a matched filter pair and do not result in

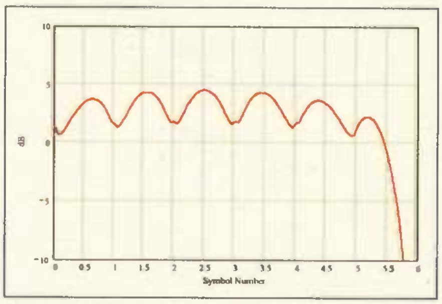

Figure 4. Sum of the sequence of RRC-filtered symbols.

a raised cosine Nyquist filter. ISI is produced as a result of this change.

In the previous section, we examined the probability of a given peak level occurring. We did not address how much ISI would be generated if there is insufficient headroom to reproduce those inter-symbol peaks at the transmitter output. Indeed, that is a difficult question to address analytically.

The amount of ISI generated and the amount that can be tolerated at the receiver may be determined either by simulation or by empirical measurements. One method of determining the required backoff is to set up a test communication link and measure the threshold degradation that occurs as a function of the transmit power. It is important that the receive power level

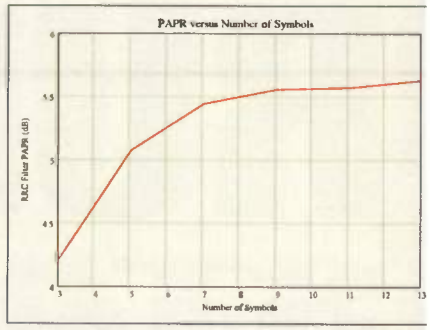

Figure 5. PAPR of an RRC filter response as function of the number of symbols in a wors case sequence.

be kept constant and that the receive be run right at threshold so that it dis plays maximum sensitivity to ISI. Wit this configuration, it is possible t determine the transmit output powe level where threshold degradatio becomes a problem.

Figure 7 shows a measured plot o effective receiver threshold as a fun

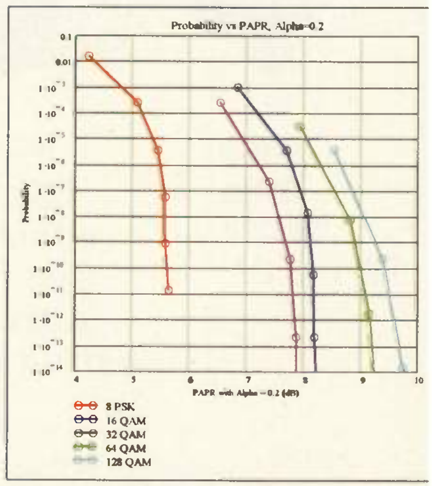

Figure 6. Probability of reaching a particula PAPR for various modulations.

tion of average transmit power. Th output back-off points suggested by th waveform PAPR are shown. Note tha there is a perceptible amount of thresh old degradation even before the theo retical back-off points are reached. Thi may be attributed to the ISI generate by the transmitter distortion of peak that approach, but do not exceed, the dB compression point.

It is also interesting that the 32 QAM sensitivity degrades at a steepe rate than the 16-QAM. This can b attributed to the fact that the E_b/N_0 o the 32-QAM signal is higher at sensi tivity than the 16-QAM signal. The IS produced by compression is relative t

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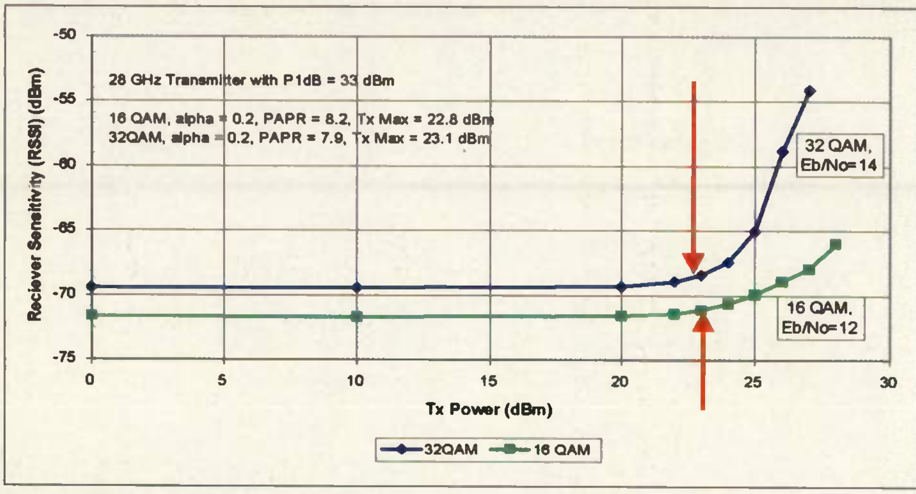

Figure 7. Effective threshold vs. transmit power.

the bit energy, so it has a greater impact on the higher E_b/N_0 signal.

Determining the final operating point

How the final operating point is chosen depends on the application. The key system performance parameter is system gain, defined as the transmit power minus the receiver sensitivity. Sometimes, both the transmit and receive antenna gains will also be included in the system-gain computation. Maximizing the system gain will maximize either the maximum possible communication distance or the receive signal-to-noise ratio. Increasing transmit power is one way to increase system gain. At the receiver, reducing the noise figure results in a better sensitivity and increased system gain.

For a system requiring high reliability or applications involving mass production, the designer will usually opt to stay out of compression entirely and maybe even add one or two dB of margin. For custom systems in which every bit of system gain must be extracted, the designer may choose to consider a plot of the net system gain and set the transmit power to the point that maximizes system gain.

Figure 8 shows such a plot for a system that was recently tested. As the transmit power is increased, eventually the point is reached where each additional dB of transmit power produces more than 1 dB of threshold degradation. From the plot in Figure 8, the point of maximum system gain is readily apparent for 32-QAM and is close to the power predicted by the PAPR.

For this system, when running 16-QAM, the compression effects are more gradual and the system gain does not present such a clear maximum. This difference may be attributable to the fact that the coding was slightly different between the two modes and, as mentioned earlier, the higher E_b/N_0 32-QAM system would be more sensitive to ISI. Both modulations were run using a concatenated Trellis code and Reed-Solomon code.

Referring to Figure 8, it is apparent that operating this 16-QAM system in compression can provide som increased system gain. As the power i increased, the system gain curve flat tens out, and increasing the transmi power by 25 dBm does not actuall increase the system gain. In this case there appears to be an incentive t operate 2 dB into the compressio region of the transmitter. This must b balanced against the effects of the dis tortion on receiver performance and th risk of the operating point moving fur ther into compression as component age, power supplies vary and othe real-world effects take their toll.

Maximizing the overall system gai by running into compression is general ly not considered good design practice When running QAM slightly com pressed, the system sensitivity is bein set, in part, at the transmitter rathe than by the receiver noise figure. Th derivation of the matched filter as a optimal detector is based on th assumption of additive white Gaussia noise (AWGN) and a linear, time invariant receiver filter[2,3]. The effects o transmitted distortion will neither b white nor Gaussian and the compres sion effectively changes the transmi spectrum, so the receive filter is n longer matched to the transmitted sig nal. In this case, the detector will n longer be optimal, which may lead t unexpected results. The signal distor tion may also impact the operation o blind channel equalization if it is used.

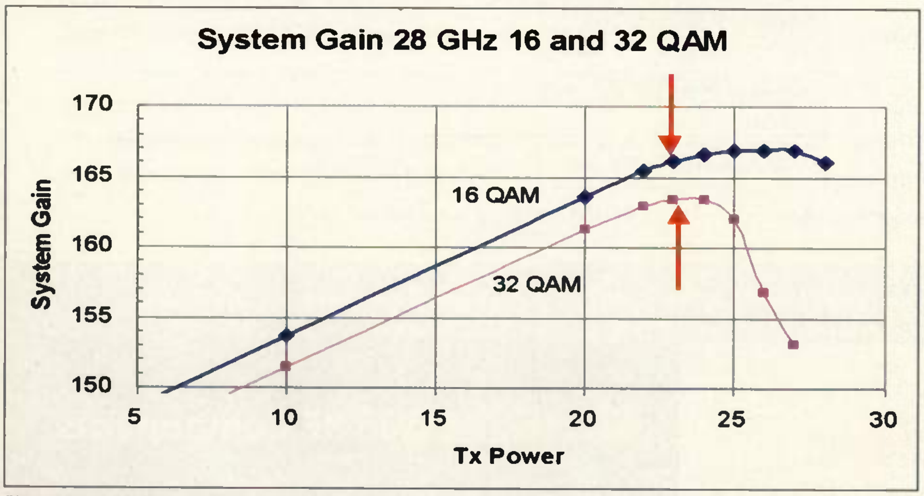

Figure 8. Net system gain vs. transmit power.

Don't forget about interference

Another consideration when pushin the transmit power is that most com munication systems have a regulator spectral mask that they must meet t limit interference to neighboring users.

When the transmitted signal is dis torted (compressed), the signal wil begin to exhibit spectral regrowth. Thi regrowth may cause the system to fai certification testing. For all of th aforementioned reasons, the bes designs will usually be achieved b operating in the linear region of th transmitter and investing in receive noise figure improvement.

For most systems, an operating poin somewhere between 1 dB into compres sion and 2 dB below the compressio point is ideal.

Conclusions

For standard digital modulatio techniques that use RRC filtering, i is possible to compute the maximum

theoretical output-back-off that i required to prevent transmitter non linearities from introducing ISI into communication link. This theoretica back-off is a combination of the PAPI of the constellation and of the RR(filter for the particular value of that is used. It is also possible t determine the acceptable probabilit of ISI and adjust the output back-o accordingly. Finally, if high transmi power is important, the designer ma elect to use system threshold degra dation measurements as a means o determining the level of peak com pression that can be tolerated for given communication system. Th generally accepted approach is t determine the PAPR of the filtere constellation and then use a figur near that value for the output back off. Performance improvements ca then be gained by improving th receiver noise characteristics.

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www.zetex.com

Reference book introduces spring contact probes

Synergetix announces a new refer[-]ence book, *Spring Probe Technology i[n] Product Connector Applications.* Th[e] book is intended to introduce design engi[-]neers to the concept of using spring con[-]tact probes as electro-mechanical inter[-]connects. The book provides a technica[l] overview of spring probe technology an[d] discusses the appropriate product connec[-]tion applications for this technology. Dat[a] and research are provided in diagram[s] and charts comparing spring probe tech[-]nology to other methods for interconnec[-]tion. Several multiple-cycle technologie[s] are compared with s-ring contact probe[s] including: wire sleeve, bent metal, wir[e] mesh, pin and socket, permanent mount[-]ing and conductive elastometers.
Synergetix
www.synergetix.com

Applications extend Bluetooth reach

TDK Systems announces three iew software applications for its "go blue" range of Bluetooth products: TDK Mobile, TDK Dialer and TDK blueDial. TDK Mobile allows users to control and manage their Bluetooth-enabled mobile phone from a PC or aptop using TDK Systems' Bluetooth PC card or USB adapter. Users can easily back up their mobile's phone book and SIM card memory to their PCs. This makes valuable contact details accessible in case of phone heft or loss. TDK Dialer adds new features to blue5 and blueM, the TDK Systems' Bluetooth solutions for Palm users. It enables users to dial any of he 4,000 numbers stored in their Palm database, directly from the PDA via a Bluetooth phone. With both TDK Mobile and TDK Dialer, sending SMS ext messages is easier and faster as hey can be written on a keyboard or using the PDA writing function – nstead of using the ten small keys of a cell phone keypad. TDK blueDial is designed for the TDK Systems bluePAQ device. The new application allows numbers to be dialed from the iPAQ contacts list and SMS messages to be edited and sent.

TDK Systems
www.tdksys.com

Bus analysis tool offers graphic capabilities

SBS Technologies introduces the next-generation PASS 3.0 software for MIL-STD-1553 and ARINC 429/575 bus analyzer capability. PASS 3200 Version 3.0 is developed for use in avionics systems integration, simulation and testing. PASS 3200 takes full advantage of ActiveX, COM and multitasking functionality by using the latest in 32-bit Microsoft Windows technology. Version 3.0 includes a full suite of advanced features and functions offering expandability and application for use in the laboratory, in flight, on the flight line, or in any application requiring real-time data acquisition and analysis.

SBS Technologies
www.sbs.com

Development tool for satellite systems

OctoGroup S.A. announces Visionic, a development tool for satellite ground stations monitoring and controlling (M&C) system software. It allows system engineers to design and implement a fully customized software system for any type of satellite earth or mobile station. Visionic extends the popular CAD/CAM package, Microsoft Visio, with satellite station-related shapes and stencils. The system engineer draws a station schematic using these symbols and Visionic compiles the schematic into executable files for the M&C system. The compiled system displays the exact schematic as drawn by the engineer in a near real-time fashion.

OctoGroup S.A.
www.visionic-system.com

HIGH-SPEED DSP CORES

Reconfigurable, extendable DSP cores and subsystems for wireless handsets, digital control and speech processing

Adelante introduces its first family of RT-level DSP cores. The Saturn family of reconfigurable, extendable DSP cores is optimized for ultra low-power, high volume, cost-sensitive telecom, digital servo and speech applications that include baseband processing for wireless handsets (CDMA, TDMA, GSM, GPRS, and DECT), speech recognition, DVD, CD-ROM, and hard disk drive controllers.

Reconfigurable – Designers can expand the standard 16-bit instruction set by creating additional 96-bit VLIW application-specific instructions.

Extendable – Designers can add application-specific hardware execution units to the Saturn core processor that further increase execution efficiency and power conservation.

Low power consumption and smallest silicon area per operation – It is suitable for battery-operated and cost-sensitive applications. Built on a 0.18μ standard CMOS process technology, the core has a silicon area of 0.5 mm^2, and consumes 0.25 mW per MHz.

It has a (typical) maximum clock frequency of 210 MHz. Using a CMOS process that is optimized for power, speed or area will improve these figures significantly.

The core's architecture can deliver as many as 12 operations per clock cycle and the core can execute 420 million multiply and accumulate (MAC) operations per second. This translates to 820 million 16-bit MACs per square millimeter of silicon.

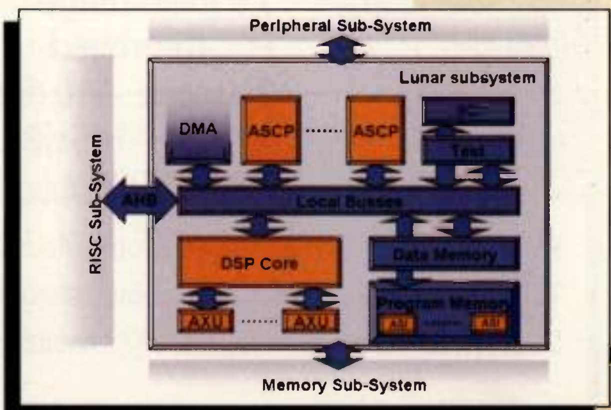
Device highlights:

- 210 MHz clock with CMOS process optimized for power and speed.
- 12 operations per clock cycle for 420 million MAC operations per second.
- ALU combination offering two 40-bit ALUs for high-precision calculations.
- On-chip JTAG emulation and run-time debug support.

Dual-Harvard architecture – It includes two 16-bit multipliers, four 16-bit arithmetic logic units (ALUs), two address calculation units, barrel shifter, a program control unit, a hardware loop control unit, a saturation and shift unit and a bit manipulation unit. There are two data memories, each of which can be as large as 64 K words by 16-bits. The ALUs can be combined to create two 40-bit ALUs offering high-precision calculation capabilities for such applications as speech and audio processing. Pointers are switched in the same clock cycle, enabling the immediate execution of service routines.

Instruction set optimized for wireless baseband and digital control – The core has 16-bit and 32-bit instructions that have been optimized for the execution of wireless, speech and digital control functions.

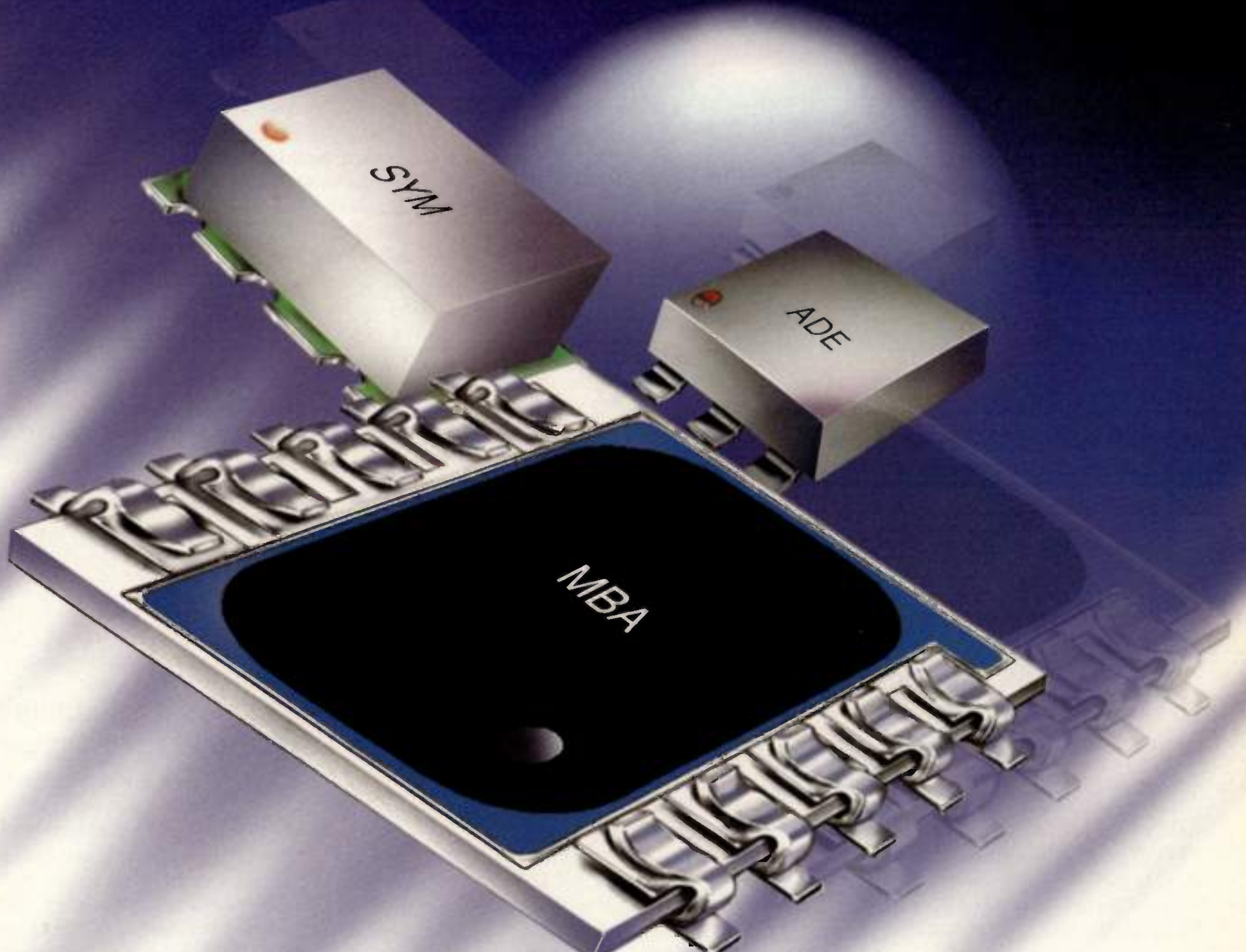
Adelante
www.adelantetech.com



High-speed DSP cores, supporting IP, subsystems and tools for the development of complete DSP subsystems for multiprocessor systems-on-chips.

WIDEBAND

HIGH IP3 MIXERS



+4 to +17dBm LO from $6.95 (ea. Qty. 10)

Now you can obtain *spectacular wideband IP3 performance* at a value price with Mini-Circuits team of MBA, ADE, and SYM mixers. Optimized to deliver the highest IP3 for a given LO drive, these affordable surface mount mixers range from 32dBm IP3 for +17dBm LO power...to 15dBm IP3 for LO down to +4dBm. In terms of E Factor (IP3 Figure Of Merit), these mixers go as high as 1.5 providing superior intermodulation suppression from 5 to 5900MHz while at the same time achieving low conversion loss and high isolation. You'll also be pleased to know the Blue Cell™ MBA model covers your higher frequency designs with superb temperature stability, high repeatability, and ultra-thin 0.070" profile. Now, high IP3, higher performance, and value pricing have merged. The result is Mini-Circuits wideband high IP3 mixers...the *clear* choice!

Mini-Circuits...we're redefining what VALUE is all about!

Typical Specifications:

Model	Freq. (MHz)	LO Level (dBm)	IP3 Midband (dBm)	E Factor*	Conv. Loss Midband (dB)	Price $ea. Qty. 10
ADE-10MH	800-1000	+13	26	1.3	7.0	6.95
ADE-12H	500-1200	+17	28	1.1	6.7	8.95
• MBA-591L	4950-5900	+4	15	1.1	7.0	6.95
SYM-25DLHW	40-2500	+10	22	1.2	6.3	7.95
SYM-25DMHW	40-2500	+13	26	1.3	6.6	8.95
SYM-24DH	1400-2400	+17	29	1.2	7.0	9.95
SYM-25DHW	80-2500	+17	30	1.3	6.4	9.95
SYM-22H	1500-2200	+17	30	1.3	5.6	9.95
SYM-20DH	1700-2000	+17	32	1.5	6.7	9.95
SYM-18H	5-1800	+17	30	1.3	5.75	9.95
SYM-14H	100-1370	+17	30	1.3	6.5	9.95
SYM-10DH	800-1000	+17	31	1.4	7.6	9.95

*E Factor = [IP3 (dBm) – LO Power (dBm)] ÷ 10. See web site for E Factor application note.
ADE models protected by U.S. patent 6,133,525
• MBA Blue Cell™ model protected by U.S. patents 5,534,830 5,640,132 5,640,699

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ISO 9001 CERTIFIED

F 345 Rev A

Extended bandwidth microwave spectrum analyzer

Tektronix announces a new addition to its line of microwave measurement solutions. The FSU26 microwave spectrum analyzer increases the FSU family of instruments' range from a maximum of 8 GHz to 26.5 GHz. This addresses the needs of emerging 3G mobile technologies, satellite applications and more. It offers a degree of accuracy that minimizes measurement uncertainty, permitting narrow measurement margins (tolerances) without an increase in yield-eroding false passes or failures. The instrument's dynamic range is similarly matched to the needs of critical noise and spurious measurements on 3G equipment. In addition, the memory's 10 k-point capacity is the equivalent of as many as 16 conventional displays.

Specifications at a glance:
- Enhanced GPIB transfer speed
- FFT-based filters
- –155 dBc at 10 MHz offset

Tektronix
www.tektronix.com

Digital noise generator for communications test

Noise Com introduces the NG7500, a programmable pseudo-noise and CW signal spectrum generator for RF microwave, and FO equipment testing. It offers a 70 MHz RI spectrum output, including noise and CW waveforms to emulate real-world noise and interference conditions. It features a maximum 70-MHz output bandwidth (500 kHz to 70 MHz) and noise can be controlled with a 1-Hz resolution. Parameters can be entered via keypad and/or a Windows-based GUI. It can also generate signals from data files supplied by the user and downloade via an optional Ethernet remote interface. The unit come standard with a GPIB, IEEE-488, remote interface. It pro vides digitally simulated AWGN with user-setable parame ters. It can generate any combination of noise and signals. CV signals are generated with user-programmable amplitude an frequency. Other types of signals can be included or loaded b the user via the optional Ethernet interface.

Noise Com
www.noisecom.com

Satellite radio signal generator

Celerity Systems announces the the CS2010SDARS satellite radio signal generator, for production testing of SDARS-capable radios. It features as much as a 70 dB independent S/N ratio/channel, 30 MHz of multicarrier bandwidth, and a 11.5 seconds of non-repetitive signal playback. It can also simulate adjacent channel signals, potential in-band and out-of-band interferers and replay actual, field-recorded "drive-test" signals. Targeted at both design and production test applications, it is fully network-compatible, allowing operation in automated, remote and networked environments.

Celerity Systems
www.celeritydbt.com

Optical switching card line expansion

Keithley introduces the 1 x 16 optical switches, an expansion of its model 7090 optical switching card line. These switches are typically used to route a single signal to 16 DUTs or 16 instruments. The new switches can also be used in combination with the Model 7090 1 x 4 and 1 x 8 optical versions, plus DC and RF switching cards for versatile hybrid test configurations. Its 1 x 16 cards switch optical signals in the 1290 to 1650 nm range and use single-mode fibers with FC/SPC and FC/APC connectors. All cards are compatible with Keithley's GPIB-programmable 7001 and 7002 switch mainframes.

Keithley
www.keithley.com

Integrated reliability test fo wireless semi components

Maxwell announces its new line automated accelerated reliability te systems (AARTS) for performing accele ated aging performance characterizati tests on discrete transistors, monolith microwave integrated circuits (MMIC hybrid microwave integrated circui (HMICs), and RF/microwave modu assemblies ranging from DC to 18 GH and up to 96 channels. The product fan ly supports 4, 8, 16, and 32 channels capacity with full RF, DC, and temper ture stress capabilities. The system co sists of hardware and software used initiate, supervise and record temper ture, electrical and RF performan parameters automatically througho the test duration. The devices-under-te (DUTs) are mounted in individual te fixtures that allow independent bia temperature and RF control.

Maxwell Technologies
www.maxwell.com

Probe for precision on-wafe capacitance measurements

Cascade introduces the DCP-HT probe for its AttoGuard series of par metric wafer probers. A probe t

design complements the measurement shield to enable device characterization with high signal integrity to the device-under-test (DUT). The new probes use the same signal path accessories as the existing probe series. The new design also allows greater flexibility in terms of integration for some applications.
Cascade Microtech
www.cascademicrotech.com.

Bluetooth protocol analyzer

Mobiwave announces the Bluetooth protocol analyzer, BPA-D10, targeting Bluetooth wireless device developers and manufacturers. It offers an intuitive user interface, a network connection and other sought-after features. The system captures Bluetooth wireless protocol information over the air and analyzes all levels of the protocol inclusive of the base band layer. The graphics user interface displays all the information in the form of a message sequence chart. Protocol layers are further broken down into packets and fields, and even up to basic raw data format, for ease of checking. Its advance search and filtering engine allows developers to focus on the problem area quickly and easily. The error detection and packet statistic provide information on the quality of the Bluetooth devices' radio under observation and the surrounding air space.
Mobiwave Pte Ltd,
www.mobiwave.com

Analyzer monitors environments for RF signals

AeroComm's new SA 3000 spectrum analyzer is a compact, PC-based instrument covering the 2.4 GHz ISM band. The device identifies optimal locations for wireless equipment and alerts installers to potential interference. When combined with a laptop computer, it enables comprehensive remote site surveillance at virtually any location. It interfaces to a desktop or laptop PC via a standard RS232 serial port. Its size and multiple power-supply options make it easily portable and suitable for mobile site surveys and fixed site use. Operation is menu-driven, and on-screen displays are easy to read and understand. The analyzer's software includes tools for gathering and evaluating data. Its displays can be configured to three user-selectable parameters.
AeroComm
www.aerocomm.com.

Microline oscilloscope probes

Pomona Electronics announces a new series of Microline oscilloscope probes designed to speed up and simplify testing of high-frequency, high-density circuits in limited space areas. Compatible with digital and analog oscilloscopes, the new 500 MHz bandwidth probes provide capability to test a broad range of high-frequency applications. Measuring 5 x 65 mm (diameter/length), the design enables access to miniaturized and multiple test points that are difficult to reach with standard-size probes. These probes are suitable for measurements on fine-pitch IC leads. The probe is a 500 MHz x 10 passive voltage probe with input resistance of 10 MΩ , and is rated for use in CAT II, 300 VDC and CAT I, 500 VDC environments. The probe set includes the probe handle and a 1.2-meter length cable with BNC plug. The accessory kit includes: pogo-pin

spring loaded tip and rigid tip (one each), IC tip adapter, 25 mm ground adapter, 110 mm ground lead with alligator clip, tip cover, BNC adapter, sprung hook, trimmer adjustment tool, color-coded rings and a complete set of instructions and specifications.
Pomona Electronics
www.pomonaelectronics.com

Expanded frequency coverage for GSM bands

IFR announces that it has expanded the range of the IFR 2935 GSI radio test system to cover the GSI 850 and the R-GSM frequencies. GSI 850 is a new frequency band used i North and South America wher TDMA-based mobile handsets ar being phased out in favor o GSM/GPRS handsets. The 2935 als provides for GPRS testing via option software download. Managers of te and repair facilities will now be able t

support these additional GSM fr quency bands today or in the futu when expanding their businesses t include repair and maintenance o GSM 850 or R-GSM phones. Existin system owners can upgrade the instruments instantly at IFR's We site. All new instruments ordere after April 15, 2002, will include th software upgrade.
IFR
www.ifrsys.com

Mega-zoom deep-memory oscilloscopes

Agilent Technologies introduce three 600 MHz to 1 GHz, mid-rang Infinium MegaZoom deep-memor oscilloscopes designed to accelera R&D in the communications, defen and semiconductor industries. Th units feature deep-memory MegaZoo technology, with acquisition memo depths as high as 8 Mpts per chann and sampling rates as high as 4 GS The Infinium 54830B, 54831B an 54832B oscilloscopes can capture lo serial data waveforms and recei instant responses, even with the dee est memory, and quickly zoom in an search through data with no annoyi delays. The scopes' performance h been enhanced with an 866 MH Pentium III processor with 256 M RAM. Additionally, the scopes' arch

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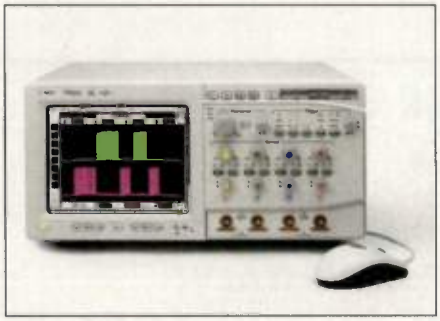


tecture supports the ports and devices generally associated with any PC, as well as remote connectivity, file-sharing capabilities and peripheral support.
Agilent Technologies
www.agilent.com

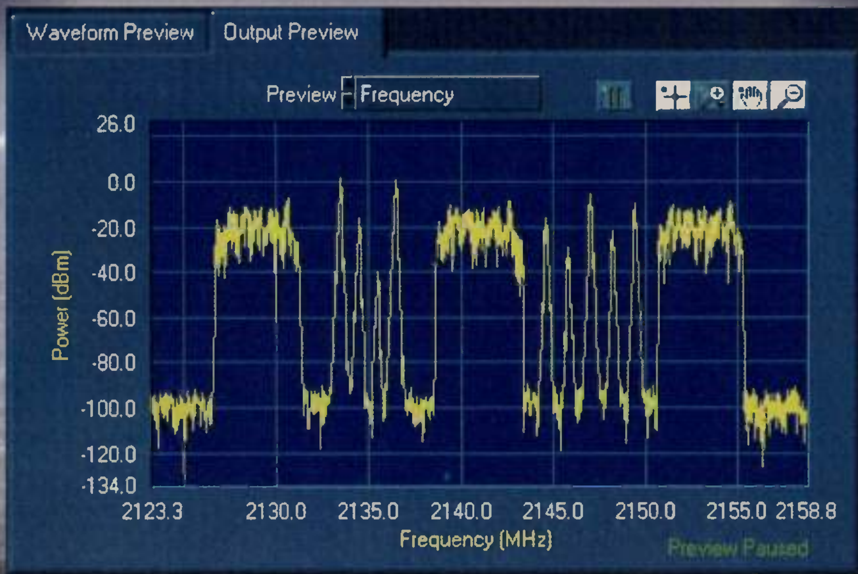
Microwave and optical GPIB switching system

Racal introduces the enhanced Model 1255A GPIB switching system with both microwave and optical capabilities. As many as four C-sized, VXIbus 1260-series switch plug-ins may be installed and mixed, providing switching capabilities for power, low-level, RF/microwave and optical signals in a single system, from DC to light. The newly enhanced system includes both an internal IEEE-488 and RS-232 interface and VXIplug-and-play-compliant drivers, making it an easy addition to any system. It also includes support for all Racal Instruments 1260-series, C-sized modules. The enhanced 1255A is suitable for dedicated signal switching in all optical and microwave systems, as well as other signal types in the 1260-series line. It contains all the necessary interfaces to develop a comprehensive switch system with significant savings over traditional implementations. The 1255A takes advantage of the density offered by C-sized VXIbus switch plug-ins, while significantly reducing cost through the elimination of VXIbus mainframes and controllers.
Racal Instruments
www.racalinst.com
sales@racalinstruments.com

Vector signal generator now shipping

Celerity introduces the second-generation CS2010 Vector Signal Generator (VSG). It has been updated to meet the needs of developers and manufacturers of NG wireless systems. Performance advances include a new graphical user interface that improves ease-of-use in both production and R&D applications. Signal files are now cached and can be externally triggered. Enhanced signal creation capability has been added to the resident Vector Signal Simulator (VSS) software. The added "Real Import" feature allows actual field-recorded signals to be replayed from the CS2010 VSG. A new high power option delivers +14 dBm RMS (up to +27 dBm PEP) across the full frequency range of the VSG and ACPR performance of 60 dBc is standard.
Celerity Systems
www.csidaq.com

Can Your Signal Generator Do This?



The CS2010 VSG Can, and More!

With all the signal generator choices in today's iarket, why on earth would someone build another ne? *Improved realism.* If your test signals don't reflect 'hat your product will encounter in actual use, how eassuring are those tests? Is it worth betting your ompany's reputation (or your job) on them?

That's why the new CS2010 Vector Signal Generator 'as developed. Whether you need to generate one gnal or a complete multi-carrier environment, no other enerator can match it for accuracy and realism. Create 'CDMA signal environments that simulate multiple base ations with individual scrambling codes, accurate GPP Test Models and precise CCDF. Or generate multi-andard TDMA carriers whose timeslots precisely ternate between GSM or IS-136 and EDGE.

Need to simulate a network evolving from 2G to 3G? A single CS2010 Vector Signal Generator can generate multiple, life-like 2G, 2.5G and 3G signals anywhere within its 30 MHz bandwidth. Only "on-the-air" signals will be more realistic!

Certainly no one ever got fired for buying from "you know who"... but people get canned every day for product problems in the field. While the CS2010 VSG can't guarantee your product's success, it can make your testing as realistic and accurate as possible. That's what we're about at Celerity.

get real.

CELERITY
DIGITAL BROADBAND TEST
L3 communications

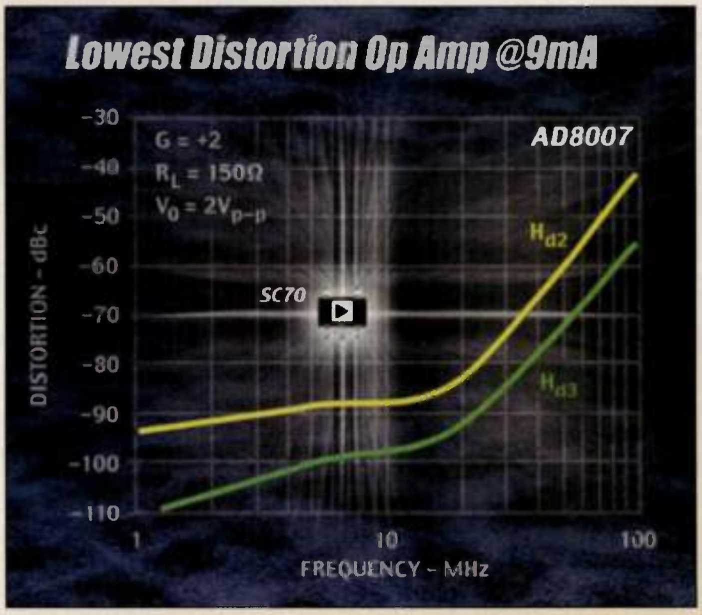
Celerity Systems, Inc.
an L-3 Communications company
10411 Bubb Road Cupertino, CA 95014
Phone: 408.873.1001 Fax: 408.873.1397

check out the CS2010 VSG
at www.celeritydbt.com.

INFO/CARD 75

Low-distortion, high-speed operational amplifier

Analog Devices announces the AD8007, a high-speed, current-feedback amplifier that features low distortion (–80 dB at 20 MHz) and low noise. The device draws 9 mA. The low power design of the device allows designers to minimize supply voltage circuitry or battery requirements, which, in turn reduces cooling requirements. This facilitates lower cost, fewer materials and/or higher density boards. Lower temperatures are a benefit as well, because they can increase system reliability and life of a product. This amplifier has 600 MHz of bandwidth (G = +1) and a slew rate of 1kV/μs. The device features a second harmonic distortion of –88 dB at 5 MHz and –80 dB at 20 MHz, while the third harmonic distortion is –101 dB at 5 MHz and –84 dB at 20 MHz. Noise specs are at 2.7 nV/rt Hz and 22.5 pA/rt Hz. With a supply-voltage range from 5 to 12 VDC and wide bandwidth, the device's applications include use in IF and baseband amplifiers, filters, ADC drivers and DAC buffers. Its low current draw and low power design means the device will not dissipate a lot of heat. This promotes device design and layout, as well as cost containment.
Analog Devices
www.analog.com



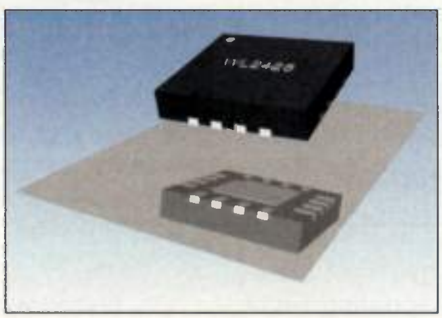
AMPLIFIERS

5 to 6 GHz WLAN power amplifier

Microsemi announces a 5 to 6 GHz WLAN power amplifier. The LX5503, a two-stage amplifier, targets the 5.15 to 5.85 GHz, medium-gain requirements found in devices such as NIC cards, mini PCI cards and WLAN access points of 802.11a, HiperLAN2 and U-NII. Designed in an advanced InGaP/GaAs HBT RF integrated circuit fabrication process, the device features a single 3.3 VDC supply, active bias, good thermal performance, input/output pre-matching and a micro-lead package with a footprint of 3 mm^2 and 0.9 mm high. At 5.25 GHz, it has a quiescent current of about 100 mA and consumes a total current of less than 200 mA, while providing a power gain of about 22 dB at an orthogonal frequency division multiplex (OFDM) output power level of 18 dBm. EVM is less than 4% at full 64QAM and 54 Mb/s. Temperature variation of gain is less than 2 dB over -40 to +85° C.
Microsemi
www.microsemi.com

WLAN 802.11b CMOS power amplifier

PowerFore announces a CMOS linear PA designed for 802.11b applications. It is packaged in a leadless QFN 4 x 4 mm package with an exposed backside for improved thermal performance. The WL2425 delivers +20 dBm of linear output power



with ACPR of -34 dBc in the first lobe (11 MHz offset) and –58 dBc in the second side lobe (22 MHz offset). It provides 30 dB of gain and draws 170 mA typical at +20 dBm output power from a single supply voltage of +3.0 VDC. This power amplifier includes an analog pin to control the output power level and supply current consumption. It also has a TTL-compatible power-up and power-down feature to maximiz battery life during receive mode.
PowerFore
www.powerfore.com
info@powerfore.com

Highly stable 1 W amplifier

Microwave Solutions introduce the MSH-5213601 1 W amplifier. Th device delivers 30 dBm of output powe and an IP3 of 39.0 dBm. Typical specifi cations are: 18 dB of gain, 4.0 dB nois figure and 1.5:1 I/O VSWR. The curren is 600 mA with +12 VDC applied. Th amplifier has been designed with sta bility in mind and incorporates a internal voltage regulator and reverse polarity protection.
Microwave Solutions
www.microwavesolutions.com

SIGNAL PROCESSING

Family of mixers with integrated LO amplifiers

Hittite Microwave introduces family of GaAs MMIC mixers with LC and IF amplifiers for cellular/PCS/3C applications. These mixers ar

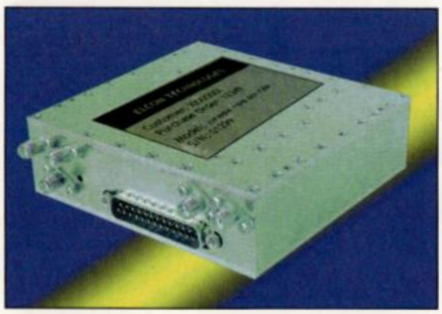
Specifications at a glance:

- Up to +29 dBm of IP3
- Up to 35 dB of RF/LO isolation
- Up to 2.5 GHz operation
- Integrated LO and IF components

designed for low-cost infrastructure applications where a combination of small size, low LO drive and high linearity/isolation is required. The 1.3 to 2.5 GHz HMC421QS16 is a high linearity downconverter RFIC coupled with a high dynamic range IF amplifier that achieves an output IP3 of +29 dBm. The HMC422MS8 and HMC423MS8 both provide 30 to 35 dB of RF/LO isolation and input IP3 of +15 dBm.
Hittite Microwave
www.hittite.com

VCO for point-to-point radio systems

Z-Communications introduces the CLV0700E for point-to-point radios operating between 680 and 720 MHz. Generating frequencies within 0.5 to 4.5 VDC of control voltage, it tunes the 40 MHz bandwidth with an average sensitivity of 29 MHz/V. It exhibits a spectral signal of –110 dBc/Hz, typically, at 10 kHz from the carrier while operating from a 5 VDC supply and



drawing 19 mA. It features 1.1:1 linearity over frequency and temperature can take the error voltage directly from the IC's charge pump circuitry.
Z-Communications
www.zcomm.com.
applications@zcomm.com

Ultra-miniature, low-jitter frequency translator

Vectron introduces an ultra-small, low-jitter, frequency translator designed for a wide variety of frequency translation and clock smoothing applications. The FX-700 is a crystal-based frequency translator that provides excellent jitter performance, high output frequencies and small package size. Output frequency ranges from 1 kHz to 77.76 MHz, with a supply voltage that can be either 3.3 or 5 VDC. The device is hermetically sealed in a 16-pad ceramic SMD package, measuring 5 x 7.5 x 2.0 mm. Applications include SONET/SDH/ATM, WDM, digital cross connect, DSLAM, DSLAR, access nodes, cable modem head ends and GSM and CDMA base stations.
Vectron International
www.vectron.com
vectron@vectron.com

Wideband VCO for wireless applications

Vari-L has developed the model VCO790-2300T that generates frequencies from 2100 to 2500 MHz with control voltages from 0.5 to +4.5 V. The unit typically requires 15 mA of current from a +5 VDC supply voltage. Typical phase noise at 10 kHz offset is –89 dBc/Hz. Typical output power is +3 dBm. Second harmonic suppression is typically –25 dBc and third harmonic suppression is typically –30 dBc. The unit is housed in a 0.5" x 0.5" x 0.18" surface-mount, pick-and-place/reflow-compatible package.
Vari-L
www.vari-l.com
sales@vari-l.com

SMT oscillators for wireless, PCMCIA applications

Designed for applications requiring extremely small size and long battery life, the S3883-32.768 kHz series surface-mount oscillator from **Pletronics** is only 2 mm in height. Supply voltage range is from 1.5 to 5.0 VDC operation. Current consumption with a 15 pF load is 9 mA max at 1.5 V_{cc}, to 20 mA at V_{cc} = 5.0 VDC. These parts have a start-up time of 500 mS or less. The standard calibration tolerance at 25° C for the parts is ±30 PPM. The standard operating temperature range is 0 to 70° C.
Pletronics
www.pletronics.com
ple-sales@pletronics.com

Low-voltage, low-current clock oscillators

Raltron announces a series of low-voltage and low-current HCMOS clock oscillators. The low-voltage 5X7 HCMOS clock is available at 1.6 VDC and 20mA with a frequency range of 30 to 70 MHz. The low-current 5X7 HCMOS clock features a supply cu rent as low as 3.0 mA at 2.7 or 3.3 VD with an upper rating of 4.6 mA at 5 V Frequency range is from 4.0 to 30 MH Both clocks offer a low jitter specifica tion of 1.0 ps RMS. Both units hav optional temperature ranges startin from 0 to +50° C to the widest of –20 t +80° C. Standard frequency stability i ±50 PPM.
Raltron Electronics
www.raltron.com
sales@raltron.com

SEMICONDUCTORS/ ICs

12 ns propagation delay MOSFETdriver

Maxim introduces the MAX504 high-current, high-speed MOSFET dr ver in SOT23 package for use in powe MOSFET switching, motor control, an high-frequency switching power su plies. The device includes two separat N-channel (sink) and P-channel (sourc outputs. It separate inverting and no inverting logic inputs are designed t operate as high as 14 VDC, regardless the V+ supply voltage and is capable

sinking/sourcing 7.6A/1.3A peak cu rent. The device's nearly constant, 12 n propagation delay over the supply vol age range allows tight control when dr ving parallel MOSFETs. Quiescent su ply current and input capacitances ar typically 1 mA and 2.5 pF, respectivel Available in the –40 to +125° C opera ing temperature range.
www.maxim-ic.com
Maxim

Addition to analog switch line

Intersil announces additions to it analog switch line. The ISL84514 an

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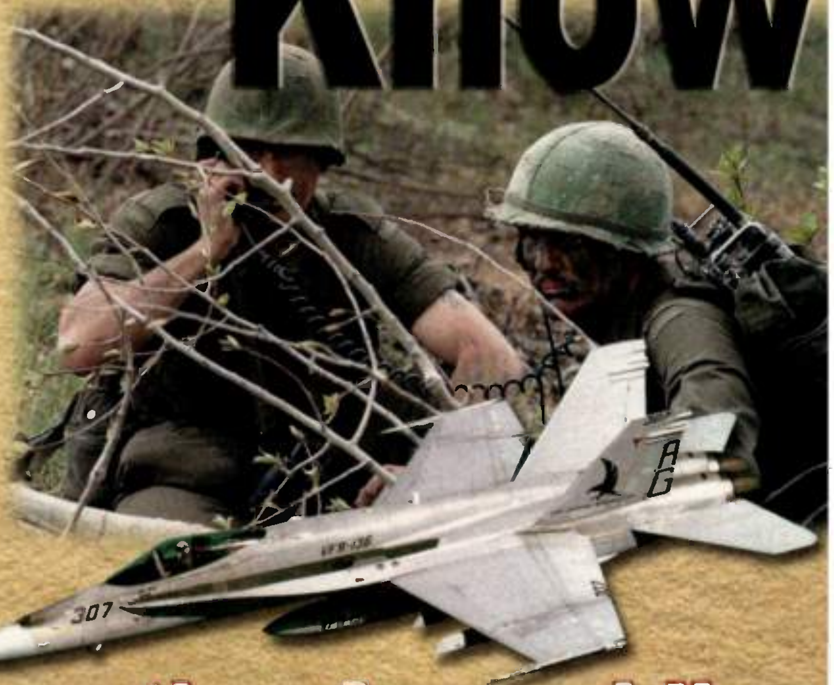
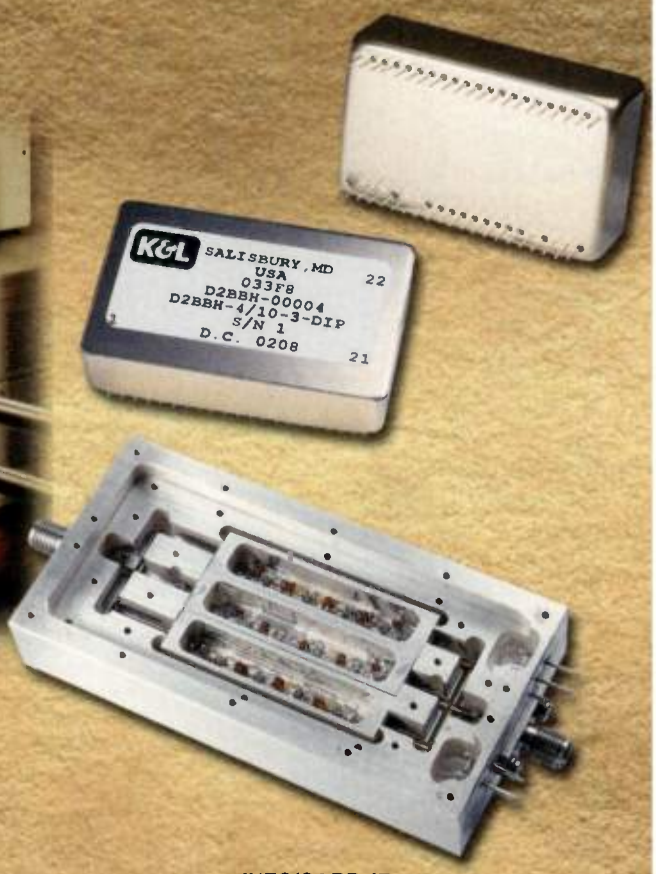
The Things You Know

K&L Microwave offers a variety of Multi-Function Assembly (MFA) products to satisfy a broad range of filtering applications. From Switched Filter Banks to Frequency Agile Filters, we offer compact, rugged packages that will endure many difficult environmental conditions, while providing excellent RF performance. For all the things you know, trust K&L Microwave to offer a solution to your complex filtering requirements.



K&L's Multi-Function Assemblies

The People You Trust



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INFO/CARD 47

the ISL84515 are single-pole single-throw (SPST) NO/NC switches. Targeted applications include portable battery-powered equipment in which space and power consumption are concerns. The devices offer low power consumption (<5 μW) and low leakage currents (1 nA max), increased hold times in sample-and-hold-circuits, and fast switching speeds (t_{ON} = 150 ns max, t_{OFF} = 100 ns max). They also reduce propagation delay in timing sensitive applications.

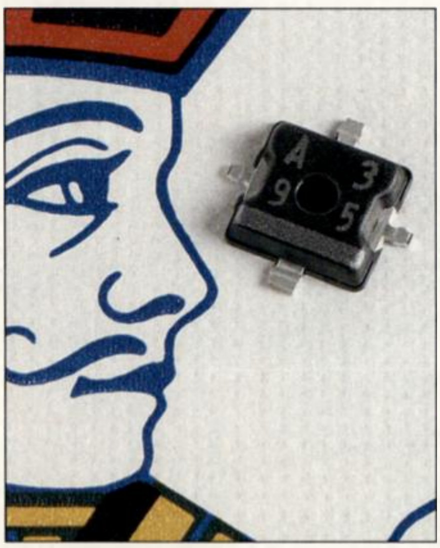
Intersil
www.intersil.com

Specifications at a glance:

- +2.4 to +12 VDC single supply
- low charge injection, 10 pC max
- TTL and CMOS compatible
- Minimum 2kV ESD rated

Silicon LDMOS FET medium-power amplifier

CEL announces the addition of an NEC silicon LDMOS FET, the NE5520379A. The medium-power device is useable from UHF to 2 GHz.



It is designed for battery voltages from 3.2 to 7.5 VDC, making it useable in a wide variety of handset and portable applications. It features high output power, high linear gain, and high PAE in a low-cost plastic, surface-mount package.

California Eastern Labs
www.cel.com

EMBEDDED SYSTEMS

2.45/5.2 GHz dual-mode chip antenna

Phycomp has developed a 2.45/5.2 GHz dual-mode chip antenna. The chip antenna meets both the IEEE 802.11b and 802.11a (2.45 GHz/5.2 GHz) requirements for high-speed, wireless data communication. Based on high-frequency ceramic materials, it is capable of achieving resonance at frequencies as high as 10 GHz. The antenna has a standard SMT form factor, small size, low mass (weight) and a built-in 50Ω impedance matching over external (helical or wire) antennas. It is manufactured using LTCC.

Phycomp
www.phycomp-components.com

Embedded analog circuit solution

Barcelona Design has released the Prado synthesis platform and analog circuit IP engines, and the Miro Class clocking engine. Customers can now implement complex, optimized analog and mixed-signal functions in a matter of minutes and hours instead of months. Each engine provides designers with function, topology and process-specific models that enable synthesis of custom analog circuits. It features a high-powered solver that can handle millions of equations and constraints in a matter of hours, high-performance router scalability to accommodate multiple engines and an intuitive flow-based user interface. The Miro Class CGS18T PLL engine features a TSMC 0.18um CMOS process, clock generation/clock synchronization functions and topology and PLL specifications of up to 2 GHz frequency and jitter as low as 5 ps.

Barcelona Design
www.barcelonadesign.com

ARM11 microarchitecture launched

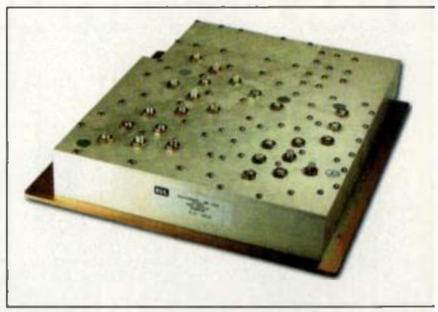
ARM introduces the ARM11 microarchitecture for next-generation wireless and consumer devices. It targets a performance range of 400 to 1,200 Dhrystone MIPS for low-power, low-cost battery-powered and high-density embedded applications. It is suitable for 2.5G and 3G mobile phone handsets, PDAs and multimedia wireless devices, home consumer applications such as imaging and digital camera applications, and home gateway and network infrastructure equipment. The architecture will deliver 350 to 500+ MHz worst-case on 0.13µ foundry processes, and more than 1 GHz on next-generation 0.10µ processes. It achieves optimum power efficiency single-issue operation with out-of-order completion to minimize gate count.

ARM
www.arm.com

TX/RX

High Q, low insertion loss cavity

K&L debuts the WSD-00216, a high Q, low insertion loss, cavity duplexer for China Unicom's CDMA IS95 and 2001X market. It allows the server to operate over a receive band of 824 MHz to 834 MHz and a transmit band

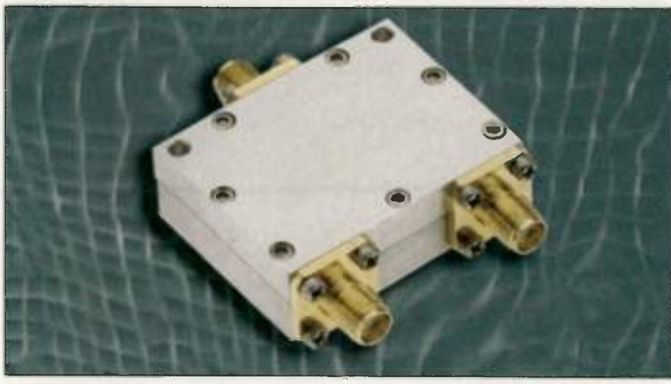


of 869 MHz to 879 MHz. The duplexer demonstrates an insertion loss typically <1.0 dB over the receive and transmit bands and has a co-channel rejection of >90 dB. The electrical performance is guaranteed to operate over a temperature range of 0 to +60°C with a power rating of 100 W average and 1500 W peak.

K&L Microwave
www.klmicrowave.com

Two-way Wilkinson power divider

BroadWave Technologies introduces a two-way Wilkinson power divider that operates over a broad frequency range of 800 to 3500 MHz with 20 dB minimum port-to-port isolation. Model 151-011-002 offers power division asymmetry of ±0.3 dB, a VSWR



1.4:1 maximum, an insertion loss of 0.7 dB. Input power rating is 5 W, CW. Standard connectors are SMA and other configurations including four-way, six-way, and eight-way are also available.
BroadWave Technologies.
www.broadwavetech.com
sales@broadwavetech.com

16-bit SAR ADC for space-constrained applications

Analog Devices introduces the AD7680, a 16-bit successive approximation register (SAR) ADC with 15 bits and no missing codes in a six-lead SOT 23 package. The device features a throughput rate of 100 ks/s, as well as low power dissipation — 3 mW at 3 VDC and 15 mW at 5 VDC, typical. Based on the SAR architecture, there are no pipeline delays. It is designed for a wide variety of portable and battery-powered applications in medical instrumentation, control systems, remote dat acquisition and mobile communications. The ADC operate from a single 3.0 to 5.25 VDC power supply and contains a low noise, wide-bandwidth track/hold amplifier with performanc as high as 10 kHz. Data acquisition and conversion are cor trolled using the CS pin and an external serial clock, allowin the device to interface with microprocessors or DSPs.
Analog Devices
www.analog.com

SUBSYSTEMS

900 MHz spread-spectrum radio

RF Industries introduces the SS-900, a 900 MHz frequer cy hopping radio for the unlicensed ISM band. It comes in DIN rail mount with an RS-232 serial data port with a 1-V RF output. Designed for industrial and SCADA operation this 9 to 28 VDC unit will pass data transparently as well a MODBUS and Allen-Bradley protocols. Each unit is capabl of being programmed as a host, remote, or repeater/remot and connects to many off-the-shelf PLCs and other devices.
RF Industries
www.rfindustries.com
rfi@rfindustries.com

BLUETOOTH/ 802.1xx

Single chip for 802.11a/b

Bermai announces a single-chip wireless solution that ha all the benefits of 802.11a (in terms of speed, quality assur ance, bandwidth and security) at the same price point an range as 802.11b. The ultra-integrated single chip double the data-rate at half the cost and half the power of existin technology for broadband wireless applications. The chip fea tures minimal external component count, a reduced BOM multiple form-factors, backward compatibility to 802.11b an reduced power consumption.
Bermai
www.bermai.com

BlueTooth application processor

BrightCom announces the IntelliBLUE BIC210 Application Processor. It boasts enough MIPS (millions c instructions/s) and data memory to run embedded application together with the Bluetooth baseband and protocol stack. It core operates at 1.8 VDC and is available in a 10 x 10 mm BGA package. A single chip includes the application processor IC with all baseband functionality, software drivers for UART PCM/CVSD, USB host and device, the complete Bluetooth pro tocol stack and BrightAPIs with Bluetooth profile support. I supports high-speed Bluetooth USB connectivity at 12 Mb/s UART at up to 921 Kb/s and PCM/CVSD for high-quality voice
Brightcom
www.brightcom.com

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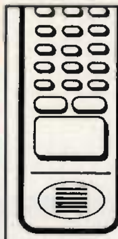

...YOUR CAREER

RF Engineering Manager: 3-5 years engineering management experience in antenna or RF related products, 5 years design experience in Wireless Communication field, and BSEE required. Manage Engineering Department for Base Station Company RF Engineer who can direct engineering activities to include design, test, prototypes, and interface with manufacturing. Must be hands-on player who can also oversee CAD, EE, ME and test technician functional reports.

RF Power Amp Design: Design and develop high-efficiency low-voltage SiGe power devices and amplifiers for cellular/PCS applications. Requirements include MS or PhD and experience in MMIC or RFIC design and test along with 5+ years experience in bipolar and GaAs power amp design.

RFIC Designers: Hands-on engineers specializing in GaAs, Si, SiGe etc. circuit design. Design centers are located throughout the US and internationally. The companies we represent will sponsor citizenship. All our client companies are successful RFIC technology leaders. All levels of engineering technology positions are open. Design, applications, project engineering, manufacturing/production. BSEE or equal experience minimum.

Senior RF Engineer/fiber-optic communications products: Must be able to design and analyze RF circuits and subsystems in the frequency range from DC to 10 GHZ. Responsible for generating schedules and meeting deadlines. Perform hands-on testing and evaluation of new designs. Provide proper documentation. Transition designs to manufacturing. 10-15 years of relevant "hands-on" experience in circuit /system design and product development BSEE (MSEE preferred) Proficiency with the RF CAD tools, ADS, Series IV, Spice, Touchstone, Eagleware, EM simulators. Familiarity with SONET and Gigabit Ethernet is a plus.

Sr. Scientist SAW Devices: Responsible for the research and development of new or modified process formulations and equipment, requirements and specifications in the manufacturing and evaluation of Surface Acoustic Wave (SAW) devices. Conceive, plan and execute projects involving understanding, defining, and selecting new concepts and approaches for new or improved processes in SAW devices. PhD/MS.

Senior Broadband Modem Design Engineer: Candidate will be responsible for the design and implementation of next generation broadband wireless access modem at speeds of 100 kb/s to 40 Mb/s, using MQAM or OFDM modulation schemes. Required candidate must have a BSEE (MSEE desired) with 5+ years RF data communications designs experience. Knowledge of TDD/FDD/TDMA techniques is preferred.

Principal Design Engineer RF IC design in the Wireless Communications and/or Broadband technologies. Experience in designing on multiple technologies such as HBT GaAs, SiGe, BiCMOS, Bipolar, is highly desirable.

RF Design Engineer Design of RF transceivers used in digital radios in the 2-6GHz frequency range. BSEE minimum, MSEE preferred. 3+ years of board-level RF and analog circuit design experience. Experience with amplifiers, filters, mixers, PLLs and their integration into radio transceivers.

Sr. Filter Design Engineer: 3 plus years experience in the design and development of RF/Microwave filters for the wireless industry. Experience with ceramic, cavity, combline, stripline, low pass, band pass filters a plus. All Filter Designers are encouraged to apply.

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INTERNATIONAL BROADCASTING BUREAU
BROADCAST TECHNOLOGIES DIVISION

The International Broadcasting Bureau (IBB) Office of Engineering and Technical Operations, a U.S. Government entity, is seeking RF System Engineers for employment in the Broadcast Technologies Division of their Washington D.C. headquarters.

The Broadcast Technologies Division of the IBB designs and builds new high power medium wave and short wave transmitting stations in both domestic and overseas locations and provides technical assistance to existing transmitting stations world-wide in support of the IBB mission to transmit Voice of America, Radio Free Europe/Radio Liberty, and Radio Free Asia programs to its overseas audiences.

As a member of the Broadcast Technologies Division, the duties of the RF System Engineer will include: **1)** development of specifications for high power medium and short wave transmitters, RF transmission lines, and related RF components including RF switches and baluns; **2)** monitoring contractor performance; **3)** providing technical support to existing transmitting stations; **4)** development of modifications to existing high power transmitters; and **5)** performing diagnostic work necessary to resolve RF related technical issues to the component level.

The candidate must have a BSEE degree and be able to demonstrate a theoretical and practical knowledge of high power medium and short wave transmitters and RF transmission systems. U.S. citizenship is required. Extensive domestic and overseas travel will be necessary. The salary will range from $35,339 to $97,108 annually. The IBB is an Equal Opportunity Employer.

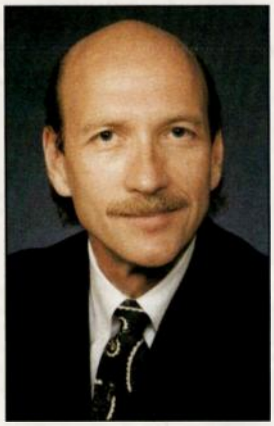
Please visit our website WWW.IBB.GOV for more information regarding the mission of the IBB.

We invite you to send your resume, or SF-171, via FAX, DHL, FEDEX, or e-mail to:

International Broadcasting Bureau Office of Personnel, Room 1543
330 Independence Avenue, SW • Washington, D.C. 20237

ATTN: Renee White • **rmwhite@IBB.GOV** • **FAX:** (202)205-8427

My money's on embedded systems



by Ernest Worthman
technology editor
eworthman@primediabusiness.com

I've been keeping an eye on embedded technology for some time. So, when I had the opportunity to attend the Embedded Systems Conference in San Francisco, I jumped at it. What I saw there really made an impression.

It isn't new, and it certainly isn't earth-shaking

In fact, embedded technology is marginally visible when we compare it to industries like DAC and µPCs. This is largely due to the fact that embedded devices are more of a support technology than a front-line technology (such as Bluetooth or 802.1xx). Embedded systems are core systems that create functionality. Most, however, are subordinate to breaking technology and are likely to stay that way.

But...bet on it!

Nonetheless, what I saw at that conference looked like a sleeping giant awakening to challenge the 21st century. And, here's an eye-opener for the RF industry: Of all the companies dealing in embedded technology, about 70% consider wireless an integral consideration in the development of embedded devices. That means that most of the design and development in embedded technology integrates one or more wireless interfaces, protocols or subsystems.

If that isn't a wake-up call for a currently stalled industry, I don't know what is.

Yes, I'm bullish on embedded. The potential opportunity for the wireless industry when it comes to embedded systems is staggering. In fact, I recently read a report that noted embedded DRAM will grow more than 20% aggregate in three years.

Why? — For the same reasons computers have become a commodity — technology marches on.

IMHO (in my humble opinion), embedded systems are the great enabler. MIPS are on a logarithmic climb, integration is up, speeds are up and new or formerly expensive technologies (SiC, SoC, SiGe, etc.) are being mainstreamed. All of this bodes for developing mini ASICs with maxi punch. Add to that the develop ment in real time operating systems (RTOS), an you've got the perfect formula for using embedde devices in smart wireless computing systems, medica devices , phones, PDAs and HUDs.

Companies like ARM, TI, Berkeley Design, IBM Analog Devices, Philips, and numerous others yet t achieve megaopoly status are developing even mor silicon-based, high-speed, high-performance digita chips that allow your portable communicator to d math, play games, download Internet pages, recogniz your voice, and...yes, even make phone calls.

IP cores, 300 MHz DACs, SoCs...and more

Most of you who follow my column know that I rarel get overexcited about much. After 30+ years of playin in the industry, I find most technologies are pretty h hum. But embedded systems have been waiting fo technology to catch up. And, now that it is, look out. I you don't get in the race, you'll likely get run over.

Many players are getting wise. I saw a lot of familia RF faces at the conference — some would surprise yo Companies in attendance included Agilent, ST Cadence, Dallas Semi, Fujitsu, Kyocera, Mento Graphics, Motorola and Tektronics, just to name a few

It's been a rude awakening

The last two years gave us a wake-up call. It wa hard for us to grasp the reality that such a downtur could happen to us. Yet we're right in the thick of it. once seemingly infallible industry — ubiquitou untethered, universal wireless communications for th masses — is stalled. And, despite the media's graspin at straws, no one really knows when things will g hoppin' again.

To the astute (OK at least to me), it seems tha now is an ideal time to investigate peripheral tech nologies — especially when one finds out that wir less is such a significant consideration in an up-an coming industry.

With the recent trend toward partnering, what do one have to lose?

It can't help but go up

That was the mantra I heard over and over. And have to admit, the momentum was there. Even *I* g psyched.

What's nice about embedded technology is that i applications seem endless. Wireless is only one se ment. But it's apparent that it's becoming a signif cant segment

So, with that in mind, if wireless were my mainsta I'd be thinking hard about embedded systems.

Ern

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Rugged Stainless Steel Construction, High Repeatability, Miniature Size, Low Cost, and Off-The-Shelf Availability are some of the features that make Mini-Circuits "BW" family of precision fixed attenuators stand above the crowd! This extremely broad band DC to 18GHz series is available in 5 watt Type-N and 2&5 watt SMA coaxial designs, each containing 15 models with nominal attenuation values from 1 to 40dB. Built tough to handle 125 watts maximum peak power, these high performance attenuators exhibit excellent temperature stability, 1.15:1 VSWR typical, and cover a wealth of applications. So contact Mini-Circuits today, and capture this next generation of performance and value!

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S2W2	S2W5	N2W5	2	±0.40
S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	±0.60
S30W2	S30W5	N30W5	30	±0.85
S40W2	S40W5	N40W5	40	±0.85

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F 331 Rev B

We took a little OFF THE TOP and LOWERED the EARS.

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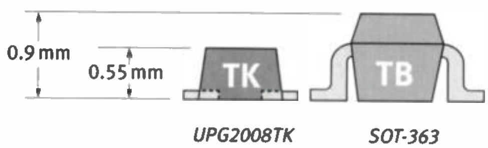


Meet the UPG2008TK. It's footprint is less than half that of a standard SOT-363 switch. Plus its leads are flat and recessed into the base of its package, giving it that super low profile your miniaturized portable products demand. Optimized for transmit/receive switching, antenna diversity switching, and power level control, the UPG2008TK is the latest in our growing family of GaAs MMIC SPDT switches.

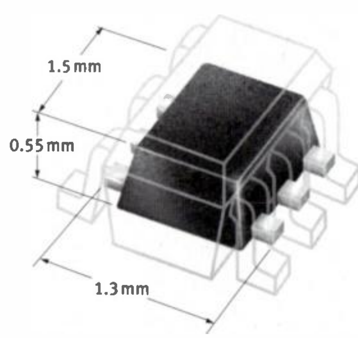
See them all on our web site at:

www.cel.com/spdt.asp

GaAs MMIC SPDT Switches

Part Number	Insertion Loss @ 1.0 GHz	P_{IN} Power Handling	Control Voltage	Package	100K Price	Description
UPG2008TK	0.4 dB	+25 dBm @ 1.0 dB	2.8 V	TK	45¢	*World's Smallest*
UPG2009TB	0.25 dB	+34 dBm @ 0.1 dB	2.8 V	TB	78¢	*High Power, No Compromises*
UPG2006TB	0.35 dB	+20 dBm @ 1.0 dB	1.8 V	TB	54¢	*Low Voltage, Great Specs*
UPG158TB	0.3 dB	+25 dBm @ 0.1 dB	3 V	TB	39¢	*Good Specs, Great Price*
UPG152TA	0.4 dB	+30 dBm @ 1.0 dB	3 V	TA	29¢	*Low Cost 3V Switch*

Applications for CEL's NEC switches include: Bluetooth, PCMCIA Cards, Cordless Phones, Digital Cellular, PCS, WLAN, and WLL.



NEC's new TK package has a 50% smaller footprint than the TB (SOT-363) package switches.

NEC | CEL

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