Future Outlook For The RF And Microwave Industry

Experts from leading RF and microwave organizations discuss what is next for this ever-changing industry and what they are doing to keep up.

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Discussing general trends in the RF/microwave design industry is tricky business for a couple of reasons. For one, the number of unique technologies that fall under the umbrella of "RF/microwave" is vast, incorporating everything from tiny discrete components to large integrated systems. In addition, the scope of application areas for RF/microwave products is nearly as broad as the number of technologies themselves, with a reach that grows wider with each passing year. As a result, meaningful trend identification becomes almost impossible because an important factor in one sector may be completely irrelevant to another.

So rather than make a few sweeping claims, this article explores a variety of niche RF/microwave design trends, each applicable to a specific technology or application area. And instead of making grand pronouncements from an ivory tower, it borrows the voices of those directly involved in the creation of the next-generation of technologies. What follows are their words, commentaries on their individual technology or application area of expertise. When viewed as a whole, however, these varied perspectives create a fascinating collage, one that accurately depicts the future outlook for the RF/microwave industry.

SiC, GaN Replace MOSFETs In Amplifier Modules

By AR Modular RF

Everyone wants something for nothing. In the world of RF amplifiers, that means wanting more RF output for less DC input, which presents a serious dilemma for designers of custom RF amplifier modules and systems. The good news is that new amplifier technologies are emerging, and these technologies are pushing us toward the goal of delivering higher output with better efficiency.

For years, MOSFETs (metal-oxide-semiconductor field-effect transistors) have been the technology of choice for RF amplifier modules. These devices have performed very well in this role, at least compared to their predecessors (high-power bipolar devices). Unfortunately, as the demand for higher output power and higher efficiency increases, the MOSFET is no longer sufficient.

In addition, growing demand for reduced unit size means that new amplifier technologies must be able to survive higher temperatures, because small packages produce much higher thermal densities. While some recent heat-sinking techniques have become very effective, new power devices are operating in more hostile environments than they did 10 years ago. As a result, RF module designers must build new packages that allow consistent amplifier function, even as it becomes hot enough to fry an egg (temperatures that would dramatically reduce the life expectancy of MOSFETs, if not cause them to fail outright).

Responding to these requirements, the latest generation of silicon carbide (SiC) and gallium nitride (GaN) devices offer improvements in both efficiency and heat load tolerance. These new designs offer the ability to build wide bandwidths and achieve improved flatness over the band, in part due to smaller junction capacitance, as shown in the 20 to 3000 MHz design pictured. Some newer devices claim to be capable of sustaining performance over significantly higher temperatures; however, field experience is still limited with these devices.

Improved efficiency does not come without a cost, literally. For example, the price of a SiC or GaN device may be 300% higher than for an equivalent MOSFET. This is not necessarily a concern if you are building an expensive and complex system, where the device cost is only a small percentage of the total cost. But if you build smaller, higher-volume RF modules, where active device costs are a significant part of the total cost, enduser price must be increased — or you may be forced to take a lower margin on an already competitively priced product.

Since many of these new devices also need higher DC voltages, replacement designs for legacy products require new power supply solutions in the system, which means significant reworking of the designs. In addition, these devices require more critically designed bias circuits than those of simple MOSFETs. Expect amplifier designers to address these concerns in next-generation SiC and GaN designs.

Predicting RF Coverage For WiMAX Deployments

By Berkeley Varitronics Systems, Inc.

WiMAX promises to deliver last-mile high-speed mobile wireless Internet connectivity, enabling Wi-Fi hotspots to connect to one another and to the Internet without reliance on broadband cable or DSL (digital subscriber line) services. Under ideal circumstances, WiMAX is projected to deliver impressive performance of 100 Mbps speed over a radius of 70 miles. Moreover, installing a WiMAX hub in conjunction with a cell tower, or even installing a WiMAX tower alone, is much less expensive than establishing wired infrastructure.

This potential has inspired some very large companies to invest billions of dollars in the installation of WiMAX equipment. As such, it has become critically important to obtain accurate coverage data — by means of drive testing — to predict RF coverage and aid in the optimization of infrastructure. When making these coverage measurements, there are two types of fading that affect signal quality: 1) terrain-based, or "slow," fading, which is caused by propagation losses, and 2) Rayleigh, or "fast," fading, caused by subtractive mixing of multiple reflected versions of a signal.

Rayleigh fading manifests itself, for example, in the form of the static noise heard on your car's FM radio when waiting at a traffic light. Upon moving a short distance, outside the extremely small region of a deep signal fade, the reception becomes clear again. This fast fading is purely spatial in nature. Hence, the goal of any coverage measurement exercise must be to obtain data that is free from the influence of Rayleigh fading and purely indicates terrain-based signal characteristics.

Many commercially available hardware-software packages filter out Rayleigh fading by employing mathematical and statistical models. One such mechanism is 40-lambda averaging, developed by Dr. William Lee. In this process, raw samples obtained from a drive study are first filtered in order to remove Rayleigh fading. The sampled data is then averaged for a time period equal to the time it takes to traverse 40 wavelengths (lambda) in the measurement vehicle. Since the goal is to average uncorrelated samples to produce an unbiased (by Rayleigh fading) average, each sample, within the traversed 40 lambda distance, should be at least the uncorrelated distance apart.

Drive testing can be conducted using Berkeley Varitronics Systems' Coyote dual modular receiver (left) and Gator stimulus transmitter (right).

For example, suppose the minimum uncorrelated distance is 0.38 times the wavelength. This means up to ~105 (40/0.38) equally spaced and uncorrelated samples can be obtained from the sampling and the filtering process, per 40 lambda distance traversed. Averaging these 105 uncorrelated samples provides an unbiased mean received signal strength indication (RSSI) value free from influences from Rayleigh fading. It should be noted that if the spacing between the filtered samples is too large, the driving speed is too fast, or the sampling rate of the receiver is too low, then there will be insufficient samples for the averaging process to be successful.

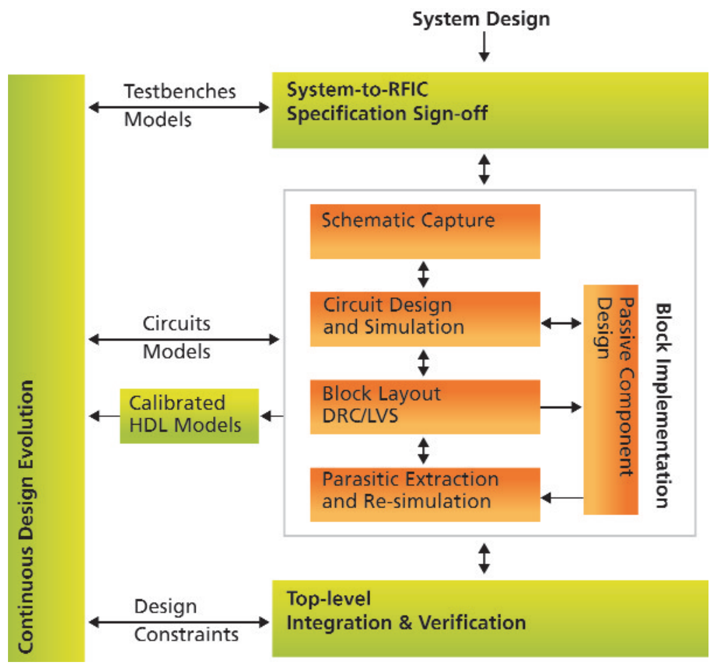
New Approaches To RFIC Design

By Cadence Design Systems, Inc.

RF integrated circuit (RFIC) design has undergone a dramatic revolution in recent years. Foundry-based complementary metal-oxide-semiconductor (CMOS) technologies have gradually replaced specialty semiconductor technologies as the process technology of choice for RF circuits. More and more designs now integrate ever-larger quantities of digital logic gates on-chip, offering designers new opportunities to integrate calibration schemes or data processing functions into their IC. At the same time, today's rapidly evolving RF market increasingly demands RF transceivers be capable of supporting multi-mode and multi-band capabilities, and capable of complementing a wide range of baseband processors as well.

Each of these developments has had a major impact on the RFIC design flow. Together, they have forced engineers to develop increasingly dense and complex solutions, which require challenging and time-consuming integration, verification, and test strategies. As RFIC designs run into the millions of transistors with increasing amounts of mixed-signal content, designers must quickly and efficiently verify their solution across multiple domains. Moreover, time-consuming modeling, extraction, and re-simulation of parasitics now pose a real threat to first-time silicon success and the design team's ability to meet time-to-market goals. Clearly, traditional microwave or RF component design flows are no longer sufficient to address these many new challenges.

What RFIC designers need is a new methodology to address this increasingly complex environment — a



RF design flow

new approach to RFIC design that, by looking at the problem from a systems-level view and progressing to the transistor level, will increase silicon predictability, shorten simulation time, enable greater RF design productivity, and in the process shrink the design cycle. This new methodology must link systems-level design with IC implementation, address the key challenges of RFIC design, and allow the designers to accurately, but rapidly, verify their complete design across digital, analog and RF domains. In order to support efficient application of the required EDA technologies, this solution must include a pre-packaged set of flows that have been proven on a representative design, which can then be quickly adapted to the designer's environment.

Supporting Next-Generation Digital RF Technologies

By Tektronix, Inc.

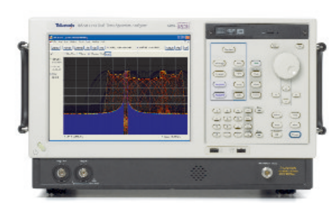
The power of digital computing technologies has fully arrived in the radio world, a development that has had a profound impact on traditional RF applications. For example, digital computing has greatly increased the pace of innovation. It has also led to the growing availability of more powerful, specialized, and inexpensive integrated mixed-signal circuits to perform analog radio functions. And these advanced "digital RF" technologies are shaping the future of wireless communications.

For example, the advent of digital RF is making possible intelligent power amplification, which has advantages in 2G, 3G, and 4G transmissions. Digital RF also supports rapid innovation in software-defined radio (SDR) and cognitive radio (CR), technologies that will fundamentally change spectrum allocation methodologies and resource effectiveness. Digital RF also enables time-varying techniques for more efficient use of available spectrum, interference avoidance, and more seamless operation.

Digital RF techniques all exhibit frequency and modulation changes that occur over time. This results in RF signals that are increasingly complex and transient in nature, and in problems that are harder than ever to find, identify, and troubleshoot. As a result, digital RF has created a need for test tools that can capture, recreate, mirror, and analyze the time-varying nature of today's signals.

Engineers need test equipment that allows them to discover the unexpected problems that are commonplace in digital RF by selectively triggering on time and frequency domain anomalies and acquiring a seamless time record of a span of RF frequencies into memory. Their test instruments must be able to solve many transient problems ranging from modulation switching on SDR systems to identification of rogue pulses in radar transmission to dynamic modulation changes during a wireless LAN (WLAN) transmission.

Signal generators will also play an important role in digital RF testing by providing engineers with the ability to exercise designs under real-world conditions. To test digital RF devices during development, designers will need to generate complex, fast-changing signals that owe as much to the digital world as to the RF world. Digital RF devices often use a low intermediate frequency (IF) or zero-IF (direct conversion) approach to producing the modulated RF signal, which means that the traditional use of analog filters is no longer easy or even feasible. The emphasis is now moving toward correction in the baseband, utilizing active nulling of gain and DC offset mismatches as well as IQ (in-phase/quadrature) imbalances. This requires digitally architected signal sources.



The DPX spectrum display on Tektronix RSA6100A Series Real-Time Spectrum Analyzers offers a live color view of signal transients changing over time in the frequency domain.

Achieving Maximum RF Signal Densities

By W. L. Gore & Associates, Inc.

Electronics processors, modules, and subsystems continue to evolve into smaller and lighter packages. The reasons behind this trend vary from industry to industry. On commercial aircraft and business jets, reduction of size and weight can be translated into increased payload capacity, increased range, or the ability to install additional features. Subsystems and processors for military aircraft are reducing their weight and footprint to allow greater mission capability. On spacecraft, the ability to reduce footprint and associated weight significantly impacts the overall satellite size and the resulting cost to launch.

Mission-critical processors and modules require the highest level of signal integrity for RF signals passed between components. The parameters defining signal integrity vary based on the functionality of the subsystem or processor. Despite the differences in signal processors, there are common goals for system electrical performance including: cross-talk, maximizing shielding effectiveness, minimizing skew, minimizing jitter, minimizing phase change (as a function of temperature), and minimizing residual (additive) phase noise.

The electrical performance goals may seem to be diametrically opposed to the mechanical goals of system designers: reduce size and weight while providing a robust mechanical solution. In the past, these two goals were mutually exclusive. This is no longer the case. By selecting high-performance RF blindmate connectors and cable, designers can achieve superior system performance while meeting their mechanical goals.

For example, new super high-density RF blindmate connectors can provide .085" center-to-center spacing and .110" overall stack height for orthogonally stacked components, while accommodating 0.00 to -0.10" axial misalignment and up to +/-.012" radial misalignment, opening the allowable mechanical tolerances for system designers. The larger tolerance band combined with a reduction in the number of ceramic layers required for the package creates a huge cost savings for the overall system. In addition, these connectors feature typical VSWR of less than 1.15:1 through 50 GHz, and provide excellent shielding effectiveness.

Although original applications focused strictly on board-to-board installations, the industry is adopting these connectors to solve additional problems. New applications require signals to be transmitted over longer distances in multiple axes, and connect using multi-port headers. In order to accommodate these needs, new cable-mount designs have been introduced including bulkhead mount shrouds, right-angle profiles, and custom headers.

By combining these new cable-mount connectors with high-performance microwave cables, interconnect solutions are achieved that can meet tight center-to-center spacing while providing a low-loss, flexible interconnect operating up to 65 GHz. Low-mass cables can be employed in varying diameters depending upon the system's loss budget and length of the overall cable run. As an example, applications inside modules where lengths are typically short, flexible assemblies provide the ability to easily route and bundle cables in three dimensions. In order to run these signals over distances measured in feet instead of inches, connectors can be used in custom assemblies with cables as large as .085" diameter.

GORE 100 Series Connectors are new high-density RF blindmate connectors that offer low profile and mass.

Using Synthetic Instrumentation To Speed Commercial Product Design

By Auriga Measurement Systems

Today's consumers — particularly today's young consumers — are adopting and demanding mobile video and other new cell phone features at a furious pace. To keep up with these changes, design engineers are being asked to send more bits over less bandwidth, use less battery power, and createproducts that are smaller, cheaper, and more flexible. In this fast-paced environment, the need to achieve first-pass success on complex, challenging designs has become paramount.

Fortunately, engineers can now deliver accurate models more quickly and efficiently than ever before by integrating new synthetic instrument-based pulsed I-V/RF measurements and modeling methodologies into their design process. This measurement and modeling approach enables designers to respond very rapidly to design parameter and condition changes, such as the modification of a bias voltage or the need to scale a device to enhance available power or efficiency.

Adding synthetic instruments to a characterization system allows for faster test results, cost savings (due to reduced footprint), and more flexibility to keep up with advancing technology. For example, by using a pulsed I-V/RF system based on synthetic instrumentation for your device characterization and modeling, you can now replace your traditional two-bay, 2-meter test system with a 1-microsecond RF pulse with a one-bay, 1.3-meter test system that is capable of 100-microsecond RF pulses, all at a significantly reduced cost.

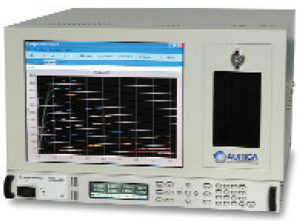
Synthetic instruments are proving a critical element in the effort to improve device models and the measurement techniques they are based upon. In addition, synthetic instrumentation gives you the ability to rapidly upgrade measurement systems as technology evolves, removing budgetary constraints commonly associated with implementing new techniques. This allows modeling and device engineers to rapidly answer the call for better models to support improvements in mobile devices.

Our youth-based culture's hunger for new features like mobile video is changing the technology drivers in the microwave industry from the government electronics sector to the consumer marketplace. While the U.S. government is, in fact, leading the charge in the development of standards and interfaces to support and encourage the growing synthetic instrument industry, the payoff will be in further reduction in test costs and associated improvements in quality and accuracy for the commercial market.

New Thermal Management Considerations For Circuit Boards

By Arlon Inc., Materials for Electronics

The electronics industry continues to drive the development of new circuit board materials to satisfy higher power and higher thermal stability requirements. Designers point to the Arrhenius equation, in which a 10 C increase in temperature typically doubles component failure rate. In other words, get the heat away from the components, reduce or eliminate hot spots, reduce overall device operating temperature, and increase product lifespan.



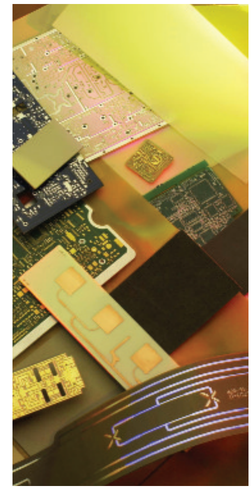
Equipment based on synthetic instrumentation, like the AU4550 Pulsed IV System picture here, is helping engineers keep pace in the demanding world of mobile phone design.

In RF and microwave applications, power amplifiers and high-power transmitter networks are major applications that demand high reliability while also pushing power density and operating temperature limits. As such, these technologies place high demand on heat rejection to ensure material life and/or component reliability. This is particularly true where passive cooling is desired from a reliability, maintenance, and size perspective. Engineering focus for these higher-power designs — where temperature extremes are normal and heat rejection is a primary consideration — require advancements and innovation in materials. New materials must exhibit: low coefficient of thermal expansion (lower CTE offers more reliable component attachment), low loss (loss creates additional heat), and high thermal conductivity to improve heat dissipation. As RF materials are typically fairly strong thermal insulators, finding the optimal balance of material properties is critical for device reliability, cost, and performance.

In the lower-frequency electronic substrate market, thermal management requirements have stimulated a quantum leap in the demand for thermally conductive printed circuit boards (PCBs) that provide a much higher degree of thermal conductivity and lower thermal resistance, when compared to conventional Flame Resistant 4 (FR-4) based PCBs. Markets requiring this level of thermal management include: automotive engine control modules, power conversion modules, and the exploding light-emitting diode (LED) lighting module market.

To complicate things, new lead-free soldering processes are also exposing materials and components to higher temperatures during manufacturing. Thus, these materials need to have a high glass transition temperature (Tg) and a high decomposition temperature to ensure survivability during lead-free processing.

In addition to increases required in thermal conductivity, other material requirements include mechanical stability and thinner PCB styles. The PCB is a thermal barrier compared to higher conducting metal and heat sinks. So the ability to manufacture stable thinner laminates serves to lower the thermal resistance barrier, just as increasing the thermal conductivity decreases the barrier. Knowing the relationship between thickness and thermal conductivity, and its effect on thermal resistance, is critical to material choices relative to other design constraints.



Advancements in RF/microwave materials are enabling designers to simultaneously push power density and operating temperature limits in their circuit board designs.

RF And Microwave Test Equipment Gets More Flexible

By Anritsu Company

In the test and measurement sector, one trend that continues to gain momentum is the need for instruments with the flexibility to measure the wide variety of digitally modulated signals that are on the market. Engineers and technicians require test equipment that can measure many different signals, whether W-CDMA/HSDPA, CDMA/EV-DO, WiMAX, GSM/EDGE, or a proprietary modulation. And they must be able to measure all these complex signals with extreme accuracy.

For test manufacturers, it also means they must develop instruments that do more than just measure signals. The new communications and modulation formats require powerful analysis capabilities. Engineers can optimize designs more efficiently when simulation and analysis tools can be used seamlessly with their test equipment. That requires an open platform that allows analysis tools such as The MathWorks' MATLAB and Simulink to be integrated directly into the instrument. The open platform must also allow for engineers to write their own tests into an instrument in order to measure proprietary signals.

Software will continue to be a strong emphasis, as well. The development of application-specific software tailored to specific standards and modulation schemes allows engineers to get a maximum return on the capital expenditure of a test instrument. It also allows engineers to use existing hardware for emerging technologies, which is a necessity in today's design and manufacturing environments.

Anritsu's BTS Master MT8222A is an example of a lightweight, handheld field instrument that accurately measures complex signals.

As data-intensive technologies such as HSDPA and WiMAX continue to be deployed, test manufacturers will have to develop field instruments that can accurately measure these complex signals yet still maintain a lightweight, handheld form factor that is easy to use. Similar to bench instruments, field solutions must be able to conduct a variety of different key measurements on numerous technologies. Their performance will also have to be similar to bench instruments, given the continued crowding of the RF spectrum.