Wireless Design & Development

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The Radiometrix QPX1 transceiver module available from Lemos International offers a 2 watt RF output VHF radio link, in a robust aluminium extruded casing. This unit is ideally suited to applications where existing lower powered transceivers provide insufficient range. The QPX1 is a multi-channel, narrowband design, suitable for licensed and unlicensed VHF allocations, FCC part 90 operation, and the 2M amateur band.
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Brainstorm

Welcome to Brainstorm!

Wireless Design Drives 3D Packaging

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Q: What are some of the challenges designers need to resolve when it comes to 3D system design and do we currently have the necessary tools to do so?

Nahum Rapoport, (above) President Remtec, Inc. and Rick Sturdivant, (bleow) President Microwave Packaging Technology, Inc.

Successful design of RF 3D systems requires excellence in three areas. The first is manufacturing materials and processes. The challenge is that complex systems require the balancing of often conflicting requirements such as highly conductive thermal paths versus low insertion loss electrical paths. An optimum solution can only be achieved through a complete understanding of the available manufacturing and material solutions. The best tool for this is a verified and automated design trade matrix, although in practice the choice of materials and processing is usually left to the most experienced and senior designers. Understanding and applying the most advanced processes such as the Plated Copper on Thick / Thin Films (PCTF®) from Remtec, Inc. is critical.

The second is signal integrity which is the design practice required to ensure that electrical signals do not degrade as they pass from one interface to another. The challenge is that as the frequency of operation increases, interconnects begin to change performance. Wire bonds and other interconnects no longer perform as simple electrical connections. Instead, as frequency increases (i.e. wavelength gets shorter), they can perform as an inductor, resonator or antenna. In addition, vertical connections used in 3D systems tend to radiate and are prone to significant cross talk issues. Proven design processes must be used such as the Signal Assurance Design Process™ from Microwave Packaging Technology, Inc (MPT). The tools used in signal integrity are full wave electromagnetic simulators. They use numerical methods to solve for the electromagnetic fields in most any arbitrary structure. Presently, these tools can be used to optimize performance and can transfer design information to/from most other design tools. In the future, these tools will be connected more directly with circuit design and physical EDA design tools.

The third area is system level design. This is the task of developing the system architecture and product design so that the top level requirements are achieved. The added difficulty in a 3D system design is that the partition of functions must address high speed signal paths and vertical connections. Advanced system design tools can interface directly with circuit design and layout.

3D systems must address the issue of compactness and the demand for high functionality. The best path to successfully compete is the use of the most advanced design tools and manufacturing processes available. An ideal solution is achieved by combining capabilities such as circuit, package and system design, packaging technology, manufacturing processes and materials - all from one source. This may be possible in a perfect world, but it contradicts the prevailing trend in contemporary electronics to subcontract package design, assembly and testing to separate outside suppliers. Therefore, an optimal solution is to integrate core competencies of a manufacturing process company that specializes in fabricating a variety of packaged products with a firm that specializes in design, test and assembly of advanced microwave and millimeter-wave packages and modules.

Lee Smith, Vice President - Product Marketing, Amkor Technology

Wireless design requirements have been the driver for 3D package technologies over the past decade. Beginning with simple wire bonded die stacks for multi chip memory requirements to logic + memory integration using a combination of die and package stacking technologies, wireless system and IC designers continue to challenge 3D package technologies to provide higher density solutions.

Last year approximately 3 billion 3D packages were produced, with the vast majority consumed by cost-sensitive handheld wireless applications. Yet the majority of the semiconductor devices being stacked were not designed as a 3D architecture which places greater pressure on package technology selection. Now, with the interest that through silicon via (TSV) interconnection has generated, designers are evaluating their new

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integration challenges as a 3D architecture. An architectural approach enables designers to apply the best interconnect and package assembly technology to optimize for cost/ performance and time to markets requirements. This shift has resulted in industry experts categorizing the next wave in semiconductor packaging as the 3D Era. An era where applications will select both the interconnection and integration methods from a platform of 3D architectural technologies mixing a host of technologies optimized to the requirements. With this technology options include:

- Wire bond, flip chip, TSV and lithography/plated interconnects
- Die stacking, die embedding and package stacking
- The integration of digital, memory, RF and passive devices

At this stage EDA tools and industry standards are not in place to address the full capabilities 3D architectures enable. The cost/performance trade offs associated with the technology platforms are too complicated for a designer to make alone and under challenging time to market requirements. As a result, the 3D Era will drive close design collaboration relationships between system, IC and package design experts until broad industry standards and true 3D architects emerge.

Hari Chakravarthula, Director, Systems Engineering, Tessera, Inc.

The challenges faced by 3D system designers include: Design: Current layout tools support single substrates stacked with one or more chips. Carrying out an integrated design across many substrates and types of interconnects required for a 3D package is challenging due to lack of simulation capability across the 3D structure.

Thermal management: Multiple high power density chips are in close proximity. The conduction to the outer surface of the 3D package is poor because of high thermal resistivity materials (substrate, over mold and die-attach). Current techniques use a large number of interconnects as thermal paths, PCBs with higher copper content or the system case as heat spreader.

Assembly: It's a challenge to maintain a low warpage structure (substrate, package, etc.) during processing of the 3D system, assure materials compatibility across the 3D structure and develop equipment capabilities for non-standard parts. The impact on reliability and yield is critical due to the high cost of losing a multi-chip system.

Performance: A 3D system typically offers electrical performance advantages due to shorter trace length, but faces challenges of low-noise power delivery and routing congestion. Performance simulation is especially important for systems consisting of multiple technologies (RF, high speed digital, analog, etc.).

Reliability: Expected reliability is lower for 3D systems compared to single chip packages due to thin chips, smaller interconnects, more materials and processing. In mobile systems, drop, vibration and bend specifications are important. Reliability issues are addressed through mechanical and structural simulation and materials testing. Current simulation software is intended for bulk materials, not suited for multiple layers of very thin materials with fine features. Software tools to support thin materials representation, adhesion modeling, failure modeling of fine features and lifetime prediction are needed for better design and assembly optimization to facilitate faster time to market.

Speaking Out on the Future Of MIMO Technology

The demand for higher network capacity and for higher performance of wireless networks continues to increase. MIMO technology offers significant increases in data throughput and link range and therefore will play a greater role in future wireless communication systems.

Q: What are some of the major advantages of MIMO systems and what applications can we expect to see in the future?

David A. Hall, Product Manager RF and Communications for National Instruments

The biggest obvious benefit of MIMO systems is channel throughput. Devices with multiple phase-coherent transmitters and receivers are able take advantage of the spatial domain of a communications channel. With multiple spatial channels in the same frequency domain channel, higher data throughput is achieved. In fact, it's well established that MIMO-based communications links can actually exceed the traditional "Shannon's Theorem" estimation. As a result, MIMO antenna systems are already used — and will be continue to be used — for high-bandwidth wireless data applications such as IEEE 802.11n, Mobile WiMAX, and 3GPP LTE. For someone browsing the internet on a wireless handset, the higher data rate would translate to faster page download times.

When looking at future applications for MIMO, it's inevitable that most commercial high-throughput wireless data links will eventually use MIMO technology. Several years ago, the wireless communications industry experienced a similar technology boost with widespread adoption of OFDM (orthogonal frequency division multiplexing) — a frequency utilization technique that increased data throughput in a given signal bandwidth. In the 1990's, the first standards to use OFDM were broadcast standards such as DAB (Digital Audio Broadcasting) and DVB-T (Digital Video Broadcasting – Terrestrial). OFDM technology has since spread to wireless data applications such as Wi-Fi (IEEE 802.11a/g/n) and WiMAX – both of which also use MIMO for the same benefit of higher data throughput. Long term, it's likely that every wireless application with a requirement for high-bandwidth data throughput will use a MIMO-OFDM channel.

Today, communications system designers continue to find new applications for MIMO technology, and many of them use National Instruments hardware and software. Because prototyping a MIMO system requires multi-channel signal generation and acquisition with a shared LO (local oscillator), these systems are extremely expensive to prototype with traditional instrumentation. However, using modular, software-defined instrumentation, many researchers can prototype next generation MIMO systems at a fraction of the cost of traditional instrumentation. Currently, researchers from around the globe are using NI tools to prototype MIMO systems for standards such as IEEE 802.11n, Mobile WiMAX, and 3GPP LTE.

Mark Buffo – Marketing Director - RF Products for Keithley Instruments Inc.

MIMO (Multiple Input / Multiple Output) is one of the most significant changes ever made to radio architecture, even though it is a fairly simple concept. If you have, for example, four transmitters (or four carriers) the likelihood of getting data from Point A to Point B should be increased by close to four times. Everything else being equal, this would take up to four times as much bandwidth.

Continuing with this example, the MIMO architecture would use four independently modulated carriers, and put them on top of each other, so you really have four separate transmissions sharing the same frequency. This multiplexing means that independent data streams can be transmitted from each antenna, thereby increasing the data rate. Conversely you can increase diversity, meaning that the same data stream is transmitted by each antenna, which increases transmission reliability.

Another key benefit of MIMO is the ability to align RF energy to specific users through Beam Forming,

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sometimes called closed-loop MIMO. Beam forming allows you to adjust the phase and amplitude weights of each antenna or transmitter to direct an RF beam at a specific user within a specific geography. The user benefit is more capacity, which is gained at the expense of greater equipment complexity (an array of transmitters, receivers, and antennas to control the direction and shape of the radiation pattern). Currently, MIMO and beam forming research for commercial radio systems involves 8×8 and 16×16 configurations to maximize voice, data, and video services delivered to a customer.

The MIMO challenge at the receivers is to demodulate back to four independent radio signals; transmitters and receivers need to be phase, time, and frequency aligned. Things get even more complicated when OFDM is part of modulation scheme. OFDM is likely to be used with MIMO, because of its capability to deal with the severe multipath channel conditions that MIMO introduces.

To help overcome these problems, Keithley has developed a new generation of RF test equipment. It's allowing MIMO, beam forming, and OFDM to become an integral part of 4G device development in LTE and WiMAX systems.

Graham Celine, Senior Director of Marketing at Azimuth Systems

Wireless transmission conditions like fading and multipath have always been considered impairments disrupting cellular communications. MIMO communication systems take advantage of these conditions to create three key advantages for wireless users — enhanced throughput delivered by sending multiple streams in parallel; enhanced range by using the multiple antennas to steer or beam form data; and enhanced data reliability by transmitting multiple copies or receiving multiple copies of the same message. Together, these three MIMO benefits deliver the ultimate wireless solution, enabling wireless broadband at the speed and reliability previously only associated with wired broadband.

MIMO systems will provide throughput >100Mbps (streaming HD video quality) when users are in good stationary coverage, and decent throughput with much less retransmission than before even when users are in areas of minimal coverage. In addition, the adaptive performance techniques afforded by MIMO will operate well in urban or rural conditions, for stationary as well as for users in motion at very high speeds. The key adopters of MIMO systems, WiMAX and LTE, have set the bar high, and to date, initial trials are meeting expectations.

The ability of MIMO technology to maintain high performance data throughput to a wireless subscriber will provide the platform for business and consumer applications that will drive mobile internet mainstream. Video on demand, business applications on the go world-wide, and voice or video calling on top of that will all operate reliably and in the end, universally.

To deliver this promise, the main challenge for MIMO systems will be to dynamically provide these capabilities as the conditions change, in order to provide the best transmission based on the conditions presented. To ensure that MIMO delivers on its promise, vendors must test and benchmark the performance and interoperability of MIMO-based devices so that they will all operate well in unison. Azimuth Systems is a provider of MIMO Channel Emulators – recreating the dynamically changing over-the-air conditions in the lab for enhanced MIMO performance testing.

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