DUAL-USE AND DEFENSE CONVERSION: A VIEW FROM THE SECOND TIER

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ABSTRACT

Since the ending of the cold war, the role of the traditional second-tier[1] defense supplier has changed dramatically. The impact of the declining defense budget has created enormous financial stress for both the prime and the second-tier microwave suppliers. While the second tier is the most vulnerable to decreases in DoD spending, because of internalization of support within the primes, it can react quickly to modify its business value proposition to a dual-use strategy. Successful ventures in the commercial microwave marketplace by "converted" DoD suppliers offer an attractive *spin-back* scenario to the government as *commercial practice* begins to approach or exceed the measures of quality, reliability and affordability sought by DoD procurement offices. This paper addresses some of the market, business and technology factors that surround and challenge the second tier in this business conversion.

MIMIC: developing the role of the 2nd Tier

Much of the current DoD-based manufacturing infrastructure implemented by prime contractors and supported by second-tier suppliers was driven by the promise, yet unfulfilled, of enormous transmit/receive (T/R) module volumes for active phased array antennas required for future ground, air and space-borne platforms. The guidelines used to generate proposals and funds for each of these platforms were directed toward the "affordable module" and stimulated a wide variety of creative system-specific technology and packaging solutions and novel variants of hybrid MIC component and fabrication technologies.

The DoD-sponsored MIMIC program followed up by sponsoring impressive advances in GaAs MMIC fabrication, and testing technologies. As a second-tier supplier, M/A-COM participated at the chip level on low-noise, power and switching processes, improving yields and implementing on-wafer testing capabilities... and demonstrated the role of the second-tier as a generic volume supplier of ICs to the primes for their DoD platforms. Having formed the basis for M/A-COM's participation in both DoD and commericial markets, these technologies have been refined and improved by the demands of high-volume markets (Fig. 1). Further requirements to *continually* lower cost in quantities exceeding *any* DoD requirement has led M/A-COM further into areas of circuit compaction, process-oriented integration techniques, plastic packaging, and high-speed assembly and testing.

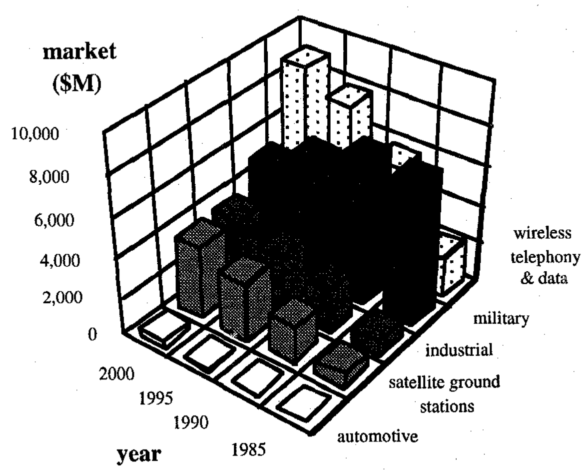

Fig. 1 Past and future global markets for military and commercial microwave applications (1993 US dollars)

As a result, the second-tier might now re-assess its role as a MMIC-only supplier and the extent to which it can and should participate in a higher value-added role as a multi-chip assembly (MCA) foundry. Many of the foundry processes that have been developed and mastered by the second-tier have the potential to bring important cost and performance leverages to MCA fabrication, assembly and testing...the scenario for *spin-back* is appealing.

1 Those companies who subcontract to the prime or first-tier systems houses.

The Need for Commercial Insertion

The intensity of effort and progress toward affordable module-level assemblies has been limited, in large measure, due to the canceling and/or stretching out of anticipated DoD programs and the volumes they might have realized. Additionally, many of us are spending R&D funds to do much the same thing without considering the potential benefits of real cooperative developments focused upon sensibly shared investments, risks and business earnings. The result is, of course, excess capacity in many of the prime contractor fabrication and manufacturing facilities that have been installed. The R&D programs sponsored by DoD, while producing innovative concepts and technologies, will require a large (most likely commercial) production demand to provide the intended benefit of affordable MCA production. For the second-tier supplier this represents an important opportunity if it can learn to service both markets from a common production technology base.

Wireless and Automotive: Models of High-Volume Manufacturing

Many of the integration concepts finding their way into T/R module designs have their roots in computer mainframe technology. Here we find the widespread use of standard practices and fabrication technologies...many of the latter paralleling our own. There is the accepted notion of a packaging hierarchy...chip, carrier, card and board each with its own attachment and interconnection technologies...many quite sophisticated including bump, flip-chip and multilayer processes and fine-pitch input/output (I/O) interfaces. The substrate technologies range from hard (ceramic) to soft (polyimide), high to low dielectric constant, and single to multilevel realizations. Many of the material properties required by computer platforms are compatible with those required for military platforms save for one critical and distinguishing characteristic: low loss at microwave and millimeter wave frequencies. It would be prudent to stay informed as the press for higher and higher data transfer rates push computing material, device and integration technology choices toward those commonly utilized by our microwave community. Opportunities to share the technology and business benefits are likely to emerge.

To venture some views concerning the future of affordable component and MCM production and the likely role of the second-tier supplier we might first explore the characteristics of the next generation mega-markets that are most likely to drive our manufacturing technologies: portable, wireless anything/everything in the near term and automotive sensing anything/everything in the longer term. It is this writer's view that if the technologies we plan to use in future DoD applications aren't also a part of the backbone of one of these major commercial revenue streams they will not help us achieve affordability. Volume utilization of a technology will dominate as the criterion for its acceptance motivates second-tier participation. Consequently, an understanding of the expectations of the wireless and automotive markets and their support technologies establishes a roadmap to achieve the affordability objectives of future DoD platforms.

The coming commercial wireless and automotive system requirements will match hardware and functional requirements of future DoD platforms (except possibly for instantaneous bandwidth). It is difficult to imagine a more aggressive communication and sensing signal environment than that which will be created by the wireless and automotive systems that will serve the global markets. Unintended and intended interference throughout the utilization spectrum (100 MHz through 100 GHz) will require the use of multi-dimensional coding algorithms, the exploitation of amplitude, frequency, phase and time techniques as well as more linear transceiver functions[2]. The traditional pace of DoD-funded technology development will be accelerated by the relentless pressure for product size, weight and cost reductions - all consistent with DoD's focus upon affordability. It is presumed that new product pricing will follow an aggressive learning curve[3]. Many of the functional interfaces are driven by regulatory standards that are rigorously applied and supported by the industry...a lesson that might well be borrowed for our own applications. While the trends are definitely toward higher integration levels, they are moderated by what is aggressively priced and available to meet the current need. For the moment the high volume needs pulled by the commercial wireless markets are focused below 5 GHz[4]. Consequently, the product implementations look very discrete and "lumpy" and somewhat inconsistent with what we would expect to see in a DoD product. In the near future, however, micro-cell sites will be linked using millimeter-wave frequencies. Automotive electronics addressing safety, Global Positioning Systems (GPS) and intelligent vehicle highway systems (IVHS) will exploit the entire spectrum served by DoD technologies. The challenge for those of us supporting DoD platforms will focus on choosing and, through dual-use strategies, utilizing the best of the resulting technologies and flexible, data-

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2 Frequency and bandwidth allocations will permit hardware standardization.

3 10% to 20% average selling price reductions per year are common.

4 cellular telephone:850MHz, personal communication networks/services, PCN/PCS:1.9 GHz, machine to machine local area networks, LAN, - 2.4 GHz).

driven manufacturing systems, adding only the incremental technologies necessary to achieve DoD's system specific objectives.

Wireless Technology Trends

Technology trends in the rapidly developing area of wireless communications provide an interesting menu of manufacturing approaches relevant to DoD applications:

At the device and component level:

- Semiconductor discretes, Si and GaAs, two- and three-terminal devices can be chosen on the basis of best cost/performance from any of many reliable suppliers. The flexibility of choice in this matter allows fundamental cost leverage at higher levels of integration.

- MMICs are used where size is important and their costs are competitive. Below 2 GHz Si is most likely to be the radio architecture workhorse in the mass terminal markets leaving GaAs to relatively confined but important niche functions of switching, and power and low-noise amplification.

- 3-volt, single-supply devices will dominate next generation portables, motivating more focus on Heterojunction Bipolar Transistor technology in preference to FET-based technology.

- Hermeticity gives way to reliability *without* hermeticity (RWoH) coatings and quality sealing practices which seem to be well-matched to product life-cycle performance even in the hostile under-hood environment of the automobile.

- Plastics and polymers are the fundamental utilization materials for high density, multilevel interconnects, rudimentary printed circuit structures and post-molded encapsulation.

- The metal lead frame, usually a copper alloy, is multifunctional; it provides structural rigidity, services the I/O interconnects, establishes the ground reference and, in many implementations, is used to remove heat.

- Packaging embraces everything that supports the reliable electrical, mechanical, thermal and I/O requirements of the active semiconductor chips utilized by the product. "Design for packagability" is inherent in cost/performance tradeoffs. Packaging remains the current dominant cost issue for commercial T/R component functions. A completely tested front-end package is desired as a "drop-in" component of the final product assembly.

- Flexible automation practices are employed for die pick-and-place procedures and fast turnaround product prototyping.

- Quality, on-time-delivery and after-sales-service are key differentiators in attracting and maintaining key commercial accounts.

At the MCA level:

- The MCM manufacturing process should have the flexibility to permit the best junction choice for each function regardless of the source. No single OEM or supplier can be expected to have it all.

- Standardized material and process data bases reinforced by comprehensive multi-dimensional predictive modeling should be fundamental elements of computer-aided engineering, manufacturing and packaging practices.

- Module circuit topologies should use transformation impedances that help to minimize junction peripheries and/or current consumption and, consequently, substrate area. The traditional 50 ohm interface restrictions may be dropped in favor of a complete, properly optimized T/R transfer function.

- The package should be viewed as an integral part of a design framework, providing a reliable mechanical, thermal, functional environment.

Next-generation MCA technologies: Thoughts from the Second Tier

- Focus upon leveraging semiconductor-based processes at the highest possible value-added levels

- First level device fabrication should exploit active GaAs, Si and/or SiGe substrates using discretes and/or junction-dominated device clusters with a minimum of passive structure content.

- Second level MCA fabrication will be based upon a 6 inch (8 inch to follow) passive substrate, preferably of low dielectric constant and 0.003 or better loss tangent at the application frequency, compatible with high resolution, multilevel, photolithographic semiconductor-based, thin-film processes. This substrate will embody most of the microscopic passive printed circuit elements, bias insertion networks and microwave/control signal interconnections. It has the flexibility to accommodate discrete devices, active clusters and MMICs which are conventionally attached and bonded or bumped and flipped to the appropriate surface pads. Second-level chip sizes can grow beyond a square inch given the yield/cost expectations of passive processing and the wafer sizes that are anticipated. For small area, low thermal dissipation applications, conductive vias, bumps and RWOH coatings would make this second level a complete MCA SMT package.

- Third level MCA fabrication, viewed as the high thermal-conductivity carrier for the second level structure. One particular approach being adopted by M/A-COM mechanically integrates the second (glass) and third (silicon) levels as a single heterolithic substrate medium. Passive silicon, a good thermal conductor has additional features of low-cost, electrically insulating (high resistivity) or conductive (highly doped) substrate. Alternatively, *active* silicon can incorporate PIN, Schottky or varactor diodes or BJTs. An application-specific lead frame can be surface attached via bumps to convey the rf and control signals and prime power. An appropriate RWoH coating and plastic cover would, as suggested above, form an MCA drop-in package.

- Fourth level MCA fabrication ...macroscopic, multilevel integration substrate for large-area (> one square inch) multifunction module applications. This substrate should be able to support low loss microwave transmission and high-density, multiple-level interconnects to integrate the MW transceiver with its analog signal, digital signal processor and prime power support functions. Thermal vias would be incorporated to remove heat from the high dissipation devices that are attached. Ceramic (LTCC) and matrix metal technologies are currently being used to implement this fourth-level MCM capability.

Pre-molded polymer packaging technology should be addressed much more aggressively as a fourth level fabrication/packaging medium, given its potential for substantial cost and weight reduction. The use of preformed metal lead frames, normally embedded in polymer packages, have potential to provide low-loss, high-current, multilevel, moderate density interconnection and while facilitating heat removal. Finally, the *factory-of-the-future* will exploit automation for intelligent die pick, flip, attach and tune procedures. These procedures will accommodate and minimize the impact of costly cross-wafer and wafer-to-wafer device parameter variances to significantly improve the yield, cost and life-cycle performance of higher value-added assemblies.

Matching the above technology issues to the core competencies of second-tier suppliers will lead to a sustainable *value proposition* to the system customer.

Summary - Focus on incremental investment.

Approaching opportunities to revolutionize component and MCM manufacturing and packaging will be fueled by the explosive growth of commercial wireless products that will service the global communications and automotive markets.

- There exists a substantial commercial technology base that can be transistioned into high quality, reliable and affordable solutions for DoD -specific platforms.
- Successful Dual-use and defense conversion strategies will give both prime and 2nd tier opportunities to address new business prescriptions that "jointly" leverage their core technologies for high volume impact in high-volume commercial revenue streams.
- The size, agility and independent, merchant status of second-tier suppliers position them appropriately to support their prime customers with a new generation of affordable component and MFA solutions that merge DoD-specific and commercial fabrication and manufacturing technologies.
- The integration and packaging approaches developed by commercial primes provide the flexibility to utilize new integration materials, including polymers, and the most cost/performance-effective active junctions.
- In the main, new DoD development initiatives at the prime and 2nd tier should embrace these approaches adding only those incremental technologies necessary to achieve system-specific objectives.
- Government sponsored programs such as Technology Reinvestment (TRP) and Microwave Analog Front End Technology (MAFET) help to motivate domestic industrial partnerships, embracing the government, prime and second-tier, that will enhance our nation's economic stability and global competitiveness...while maintaining production-readiness for our strategic DoD security platforms.