MMICs FOR COMMERCIAL APPLICATIONS
THE LOW-COST HIGH VOLUME PRODUCTION TECHNIQUES

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ABSTRACT

This presentation will cover the new and expanding commercial markets and applications for Microwave and Millimeter-Wave Integrated Circuits. Topics will include the market demand and growth, as well as examples of how the many companies addressing these demands are approaching the new volume requirements. A discussion of volume/cost relationships will be presented, along with techniques for reducing the cost and increasing functionality of Microwave and Millimeter-Wave Integrated Circuits. Specific examples from different companies will be explored with lessons learned.

BACKGROUND

Many companies who manufacture Microwave Monolithic Integrated Circuits have traversed different paths to arrive in the High Volume Commercial Market for these products, and most if not all are very happy to have found an applications promised land. The commercial market, but more specifically the wireless communication market, has brought a large although challenging opportunity to bring MMICs to the high volume cost effective point that many people in the industry have dreamed of for years. Companies such as TriQuint and Rockwell came largely from the digital direction while, others like M/A-COM and Raytheon approached from the defense side. Anadigics took a different route, focusing on the DBS market, and Hewlett Packard was addressing multiple applications. While each of these companies were off developing the IC technologies at microwave frequencies, the cellular telephone market was rapidly expanding, primarily using discrete silicon and GaAs discrete transistors to satisfy their high frequency requirements. As size requirements continued to shrink, it opened up the possibility that integration might be the answer to size, complexity, and cost. The first MMIC examples to penetrate the market were probably the silicon amplifiers from HP and Avantek, followed by silicon active mixers and GaAs switches. At the same time, Anadigics was exploring the DBS market with high frequency GaAs ICs. This is when the challenge began: “Can MMIC’s be manufactured in volume to the commercial market at a competitive price?”

THE MARKET

This discussion will make a broad description of the Commercial Wireless Communication Market which includes voice, data and video and captures systems such as cellular, PCS, WLAN, GPS, DBS, and MMDS (see Figure 1). The other significant commercial markets are the automotive and instrumentation markets. The primary focus to be addressed is the wireless market, since this is the largest near term opportunity (see Figure 2).

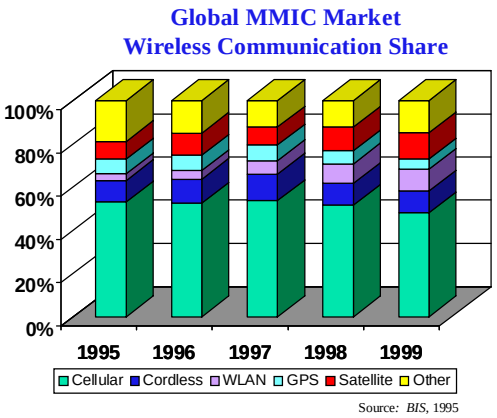

Figure 1

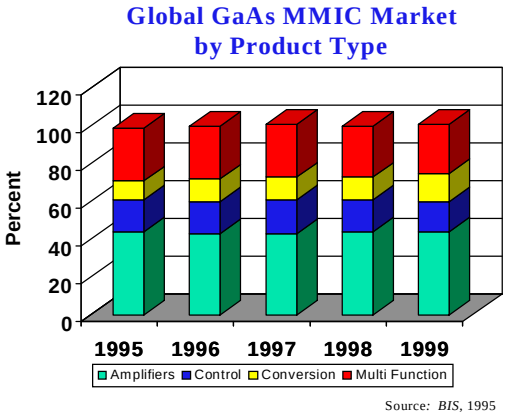

Figure 3

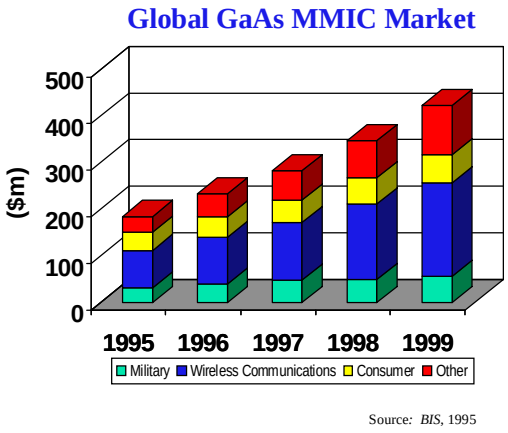

Figure 2

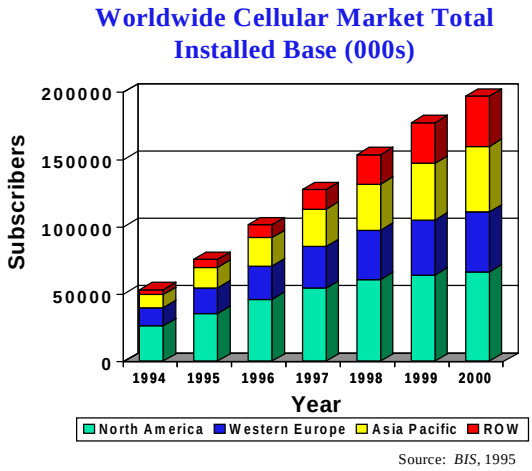

Figure 4

The cellular piece of the market can be segmented into two pieces - namely the subscriber and infrastructure segments. Both segments have significant opportunities for MMIC insertion for amplifiers, mixers and switches. (See Figure 3). Figure 4 shows the projection for subscriber units through the year 2000. The next growth opportunity is the emerging PCS market including PCS in the U.S., DCS 1800 in Europe, and PHS in Japan. Over the next few years this market is ripe with applications for MMICs due to the need for smaller phones with higher functionality, and the need for more base stations than are required for cellular systems.

Another potentially explosive voice application is for wireless in the local loop. This market has substantial possibility in countries where wired infrastructure does not exist. The difficulty with this market is with the wide variations in frequencies that are being used to deploy these systems, which limits standardization of components.

The next market application of significance is for data transmission. Both wide area as well as local area data applications are rapidly emerging. Size and cost are critical and both silicon and GaAs MMICs can find many uses. Systems beginning to emerge are CDPD, data over cellular and PCS data. The wireless LAN market has been slow to emerge due partially to

the delay in completing the IEEE 802.11 standard.

The last application in the wireless market is for video. Companies like Anadigics have already experienced significant volumes of MMIC deliveries to the DBS market. Other emerging systems such as Cellular Vision of New York's wireless cable TV system are showing volume opportunities for millimeter wave integrated circuits.

TECHNOLOGIES

The primary volume production of MMICs today is in silicon bipolar and GaAs MESFET. These technologies first proved themselves in discretes, and as the design and process capabilities were developed to integrate the matching circuitry on the semiconductors, high frequency ICs came into being. The remaining hurdle then became cost (this aspect will be discussed later). Next generation technologies are now emerging on the MMIC scene. These include GaAs HBT devices, which have the advantages of single voltage supply, high power density and low one over F noise. But as with GaAs MESFETs in the past, the tradeoffs between mature proven technologies and newer less mature processes will have to be overcome. Another technology with significant potential is silicon germanium. This material has shown good high frequency performance while using processing and equipment based upon silicon devices. This allows for the future potential of higher performance than conventional silicon at similar costs. The ability for this technology to find its way into the market will be based on the speed that it can mature and the ability of GaAs to compete with SiGe on cost and performance.

COST

Now that a high volume market existed and the technologies had been developed, although for different applications, the question became could MMICs compete with discrete solutions in volume. Figure 5 shows the percentage decrease in average selling price from 1994 to 1999 by function. There were several hurdles to cross. The first issue was "which comes first, the chicken or the egg?" Namely, the volume would not materialize unless the price was low and the cost would not drop until the semiconductor fabs were reasonably full. Several companies took the plunge and trusted that they could reach the cost targets if they got to volume. The next step was producing consistent performance in high volumes and stabilizing the processes to the point to achieve high yields. This was in the days when GaAs MMIC suppliers were proud of 50% yields. Again several IC manufacturers stepped up to the challenge and overcame these issues.

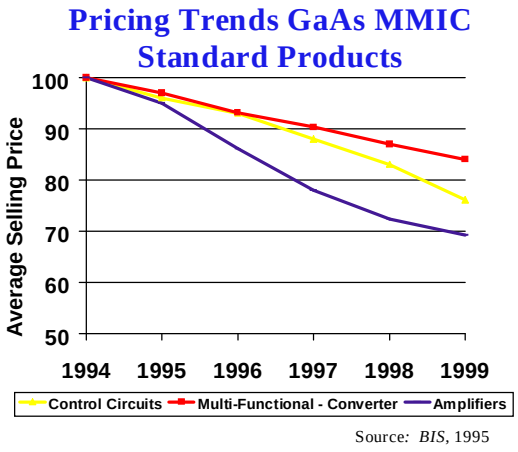

Figure 5

Encapsulating these devices in low cost plastic molded packages at microwave frequencies became the next engineering and design task, that after some experimentation was solved. Testing these devices in high volume at low cost was the last challenge that was successfully tackled.

How were all of these issues solved? As you would expect, different companies took different approaches. Certain companies

formed alliances with other companies who had similar experiences. Other companies emulated low frequency IC techniques. Some businesses chose to outsource everything from foundry services to packaging while others kept everything in-house.

There were also many different approaches to the market. Most companies began with a custom or ASIC approach to product development, but many migrated quickly to more standard products.

The levels of integration still are being explored from single function circuits to highly integrated "radio on a chip" type devices. As the integration level increases, the flexibility of the devices to function in multiple applications or systems becomes limited. As in the digital and low frequency analog industry, integration will progress as standards are developed.

WHAT DOES THE FUTURE HOLD?

There are endless possibilities and combinations. Will silicon keep increasing its frequency reach and dominate the market? Will GaAs costs continue to decline at a high rate as volumes rise and wafer sizes increase? Will SiGe or GaAs HBT's enter the market and displace silicon and/or GaAs? Will frequencies continue to increase as higher bandwidths and clearer spectrum are required? Will plastic packages be eliminated in favor of chip-on-board, flip chip, or ballgrid arrays? Will the analog section be eliminated and the signal be directly converted to a high speed digital signal processor? The answer to all of these questions is yes - for some applications and some systems at some time. The good news is that we have proven that MMICs have found their way into the commercial market and will continue to be utilized for a long time to come.