COST REDUCTION IN MANUFACTURING MICROWAVE COMPONENTS

R.M. Malbon

Avantek Incorporated
Santa Clara, California

ABSTRACT

With the rapid infusion of solid state microwave components in both commercial and military systems, cost reduction in component manufacturing has become key to affordability. Some specific areas that have had a significant impact on reducing overall component cost are: 1) device cost: 2) piece count, 3) assembly cost and 4) package cost. In the areas of device cost and piece count, the advent of manufacturable Monolithic Microwave Integrated Circuits (MMIC's) are having a dramatic effect. In the areas of assembly and packaging, automation has been the prime cost reducing factor.

INTRODUCTION

Many new systems for both the military and commercial sectors require large numbers of microwave funtions. To keep these systems affordable, significant reductions in the individual microwave component cost are required.

Usually, cost reduction must be achieved with a global solution that weighs the impact of each change. For example, it makes little sense to "engineer" a solution that saves $10 on material cost but adds $10 worth of labor content at a later step. Although for the sake of clarity, the subsets are addressed here as seperate entities, the overall solution must be constantly kept in focus. The areas where major cost reduction programs have been implemented are: device cost, parts count, assembly cost and packaging. As described below, the first two have been impacted heavily by MMIC technology. In the third, automation has played a key role. Packaging has been a significant challenge as it also entails a complete understanding of the user requirements.

DEVICE COST

One of the more remarkable breakthroughs in solid state microwave component manufacturing has been the introduction of Monolithic Microwave Integrated Circuits (MMIC's). The first to be introduced as products were low frequency IF gain blocks using both silicon and gallium arsenide technology. A typical silicon MMIC is shown in Figure 1 with a performance summary in Table 1.

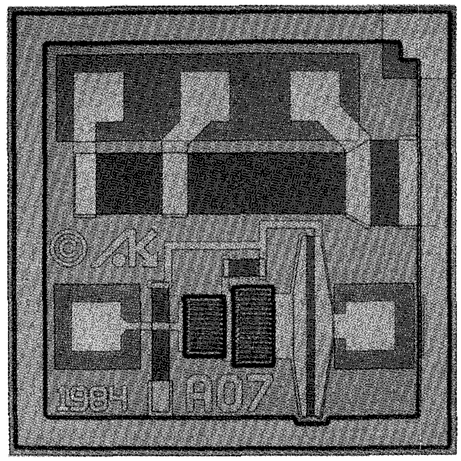

Figure 1: Optical micrograph of a Silicon MMIC

TABLE I

Silicon MODamp

$\|S_{21}\|^2$	Power Gain	12.5dB
F_{1dB}	-1dB Gain Point	1.7GHz
P_{1dB}	Output Power	0.5dBm
NF	Noise Figure	6dB

Similarly, an MMIC using gallium arsenide technology was developed and is now commercially available that exhibits good performance through 4GHz. (1) The performance specifications are summarized in Table II.

TABLE II

GaAs MMIC

Bandwidth	200 MHz - 3 GHz
Noise Figure	3dB
Gain	9dB
Output Power	+17dBm

0149-645X/86/0000-0419$01.00 © 1986 IEEE

These products achieve a performance/cost factor on the order of dollars per Db for IF gain and are available in both plastic and hermetic packages. This type of packaging lends itself to low cost surface mount assembly techniques. Not only have these products lowered direct material costs but have significantly reduced the engineering content of an IF section. This also reduces product development time which improves the return on investment on design engineering time.

What makes these chips viable contenders for low cost manufacturing applications are the chip designs. The designs combine both small size and high yield with good matching characteristics to make them useful in a variety of applications. This multi-purpose capability leads to their incorporation in a variety of products which implies high volume. The high volume permits the semiconductor manufacturer to employ all the cost reduction techniques associated with high volume semiconductor production to lower the chip cost making it even more attractive. This is discussed in detail in a later paper in this session.

As an example of the cost impact on a system, the graph in Figure 2 shows the price of a silicon gain block MMIC as a function of time. The price reduction has been stimulated largely by the tremendous increase in volume. This supports the theory that generic chip sets are the key to affordability.

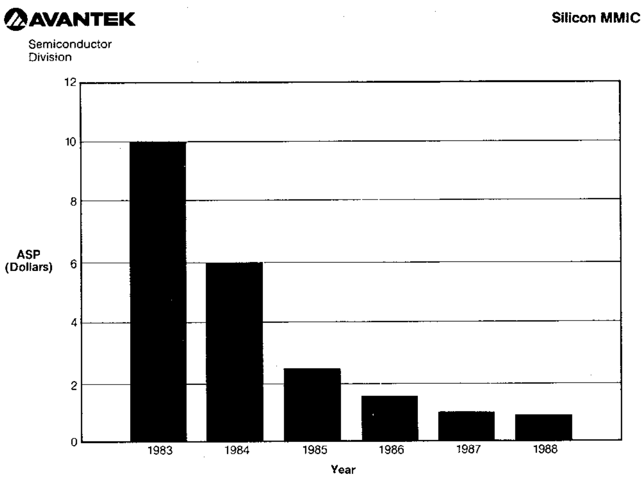

Figure 2. Silicon MMIC price as a function of time.

In addition to silicon MMICs, new GaAs MMIC designs are also becoming available commercially. With their small size and wide applicability similar impacts are expected on higher frequency RF amplification requirements.

Examples of such chips are provided in Figures 3 and 4. Figure 3 is a photo of an array of distributed amplifier MMIC's that cover the 2 to 18 GHz band. (Photo supplied courtesy of Narda)

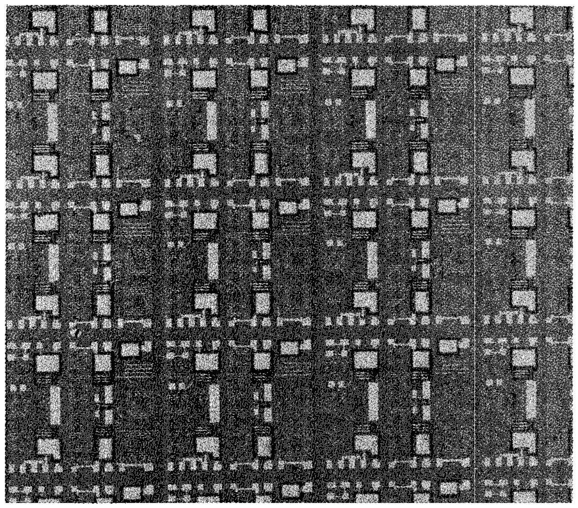

Figure 3 Optical Micrograph of an array of MMIC distributed amplifiers. (courtesy of Narda)

The basic specifications for one of the packaged products is described in Table III.

TABLE III

GaAs MMIC

Bandwidth	2-18 GHz
Gain	10dB
VSWR	2.5:1
Intercept Point	+20dBm
Power Output	+10dBm

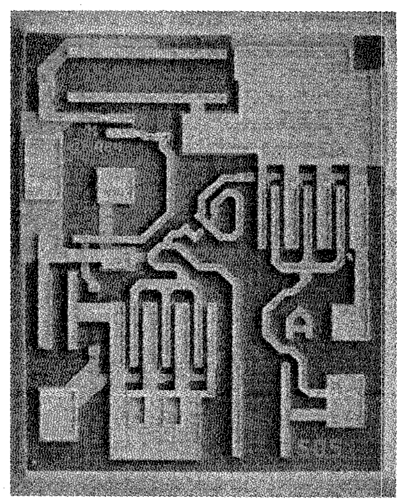

Figure 4. SEM micrograph of a wideband GaAs MMIC

The GaAs MMIC illustrated in Figure 4 is a low noise 2-12 GHz, two stage, DC coupled amplifier.

It was designed for a variety of small signal applications through X-band. Without any additional tuning this amplifier provides a minimum 8dB gain and a maximum noise figure of 5dB. The design is very compact (.53mm x .65mm) which makes it ideally suited for low cost, high volume applications. A summary of its basic specifications is provided in Table IV.

TABLE IV

Bandwidth		2-12 GHz
Power Gain	$\|S_{21}\|^2$	12dB @ 4 GHz 8dB @ 12 GHz
Output Power	P_{-1}	+11.5dBm
Noise Figure		3dB @ 4GHz 5.5dB @ 12 GHz
Output VSWR		1.5:1

With additional matching on the input, significantly improved noise figure and associated gain performance can be expected.

RF gain blocks of this type will lower the manufacturing costs of a variety of both military and commercial microwave systems. An example of a commercial system that effectively utilizes MMIC technology is the Small Aperture Terminal designed for private business communications networks. This telecommunication system operating at Ku-band uses both silicon and gallium arsenide MMIC's throughout its RF and IF sections to maintain affordability.

PIECE COUNT

Lower cost is also achieved via MMIC technology through lower parts count. A typical balanced amplifier gain stage will require two GaAs FETs, a variety of capacitors and bond wire inductors as well as positive and negative bias supplies. The new MMIC's significantly lower cost by integrating many <u>but not all</u> the parts on-chip. Especially <u>important is the</u> ability to provide biasing schemes that eliminate the dual supply requirement. This lowers complexity as well as piece count.

ASSEMBLY COST

The two most common assembly techniques for solid state microwave components use either ceramic substrates with chip devices and wire bonds or softboard circuitry with packaged devices and solder interconnects. In the thin film hybrid (chip and wire) approach the devices are individually die attached and later connected to the circuitry using gold wire bonds.

In the past, these thin film hybrid assemblies were fabricated completely manually with associated high cost. Recent advances in microprocessor controlled automatic pick and place die handlers now permit the assembly of microwave size die as small as .015" x .015" directly onto the thin film circuitry. In most cases, the equipment has been designed for the mainstream semiconductor IC industry requiring that the microwave user make modifications. However, the cost savings over manual die attach in both direct labor cost and yield improvement significantly outweigh the engineering investment.

An example of this type of technology are general purpose IF gain blocks. For this type of product, the devices (transistors or MMICs) are DC checked at the wafer level, scribed, broken and expanded on tape. In the assembly area, the expanded wafer is mounted on the pick and place machine which is programmed to pick the electrically good die off the tape and die attach it directly onto the thin film circuit. The thin film circuits themselves are fabricated in an array format with hundreds of circuits per thin film substrate. This combined with an automatic substrate feed permits the automatic die attach of thousands of circuits per hour.

For the case of softboard assemblies, dramatic cost reduction has been achieved thru automation. For these circuits, the designs must be more tolerant of device placement as the devices are typically soldered onto the circuit board. However, with the advances in automatic on-serter type of equipment the variations are predictable and can be taken into account during the circuit design. For volume applications, the devices are mounted onto reels and the automatic on-serter picks the device directly off the tape and inserts it onto the circuit board. This significantly lowers the assembly cost and is capable of handling large volumes. A photograph of one of these systems is shown in Figure 5.

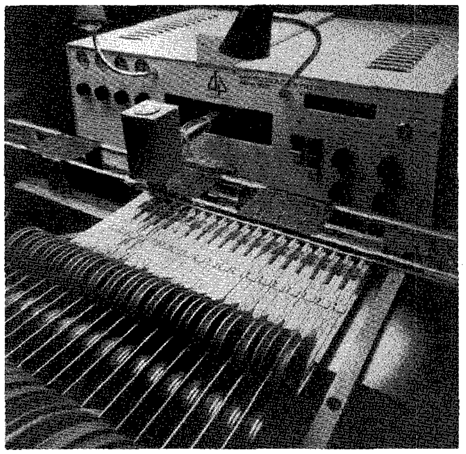

Figure 5. Photograph of an automatic device on-serter system.

An area of particular importance to overall cost as well as performance has been the packaging of solid state microwave components. Significant advances in the past few years include the development of a hermetic package that could be adapted by the users for both standard connector interconnects as well as for soldered lead interconnects. The electrical RF connectors are screwed into the housing and are removable by the user if desired for solder interconnects.

Recently, new types of surface mount packages have also been developed for microwave components. The approach is to develop lower cost packages that can be more easily integrated at the system level. This type of package lowers system cost both in terms of the lower component cost and the lower system manufacturing assembly cost.

With the introduction of GaAs MMIC's capable of excellent RF performance to 20 GHz, it has also been necessary to develop packages for these devices that do not degrade the performance and at the same time are low cost. An example of one of these multi-leaded packages is shown in Figure 6. The cost for a package of this type with excellent RF performance through 20 GHz is on the order of $5.00.

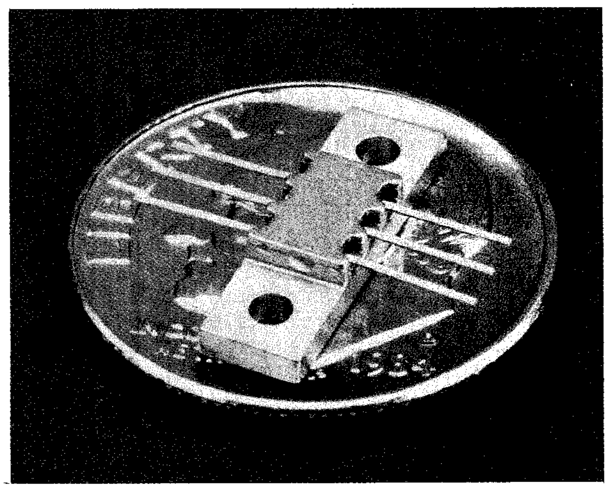

Figure 6. GaAs MMIC package for 20 GHz applications

CONCLUSIONS

The advances described above have resulted in significant reduction in manufacturing costs particularly in those applications where there are volume requirements. One example illustrating the influence of many of these factors is the TVRO component market. These units typically use the softboard/packaged device approach and take advantage of automatic assembly and test. The graph in Figure 7 illustrates the influence of these advances on the price of one of these components over time.

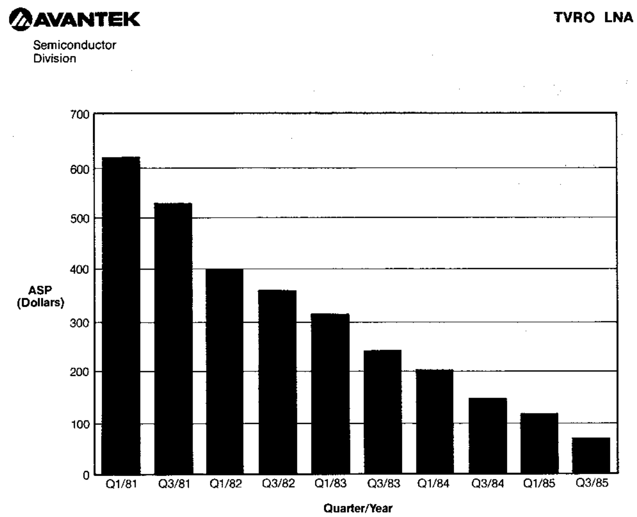

Figure 7. Graph of TVRO LNA price vs. time

REFERENCES

1) Microwave Systems News, May 1981, Pg. 114-112.