COMMERCIAL APPLICATIONS OF MICROWAVE MONOLITHIC CIRCUITS ?

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ABSTRACT

The suitability of GaAs microwave monolithic integrated circuits will be examined of different applications in the commercial (non-military) fields. A survey of such applications is undertaken together with an assessment of present day technologies which could satisfy their needs. Some conclusions are drawn.

INTRODUCTION

Monolithic Microwave Integrated Circuits (MMIC's) have only very recently become a contender for commercial applications. They developed from research curiosities, exploiting the extraordinarily good qualities of FETs in microwaves and their ease of integration (1) to full research projects (2) and are new undergoing industrial development. The two application areas are for military and civil needs but these needs are often very different, indeed diametrically opposite : small quantities for military (200 - 1000), large for civil consumer (10^5 - 10^6) for instance. They are also interested in different aspects of MMIC's, one for improved performance and reliability, the other for reduced costs in either totally new areas, or those where the costs were previously prohibitatively high. Only the second (commercial) market will be considered here.

There are two implied questions in the title :

1) Are there commercial (as opposed to military) applications for microwaves?
2) Are monolithic microwave circuits feasable in a commercial context?

These questions will be examined in this paper although it must be appreciated that they can only be satisfactorily answered after the market has appeared and such opinions as are expressed here can only be taken as tendencies.

To examine these questions in more detail it is useful to compare the different technologies for a particular application. Fig. 1 compares the current contenders in a general case where cost per circuit for a particular function is drawn against frequency for GaAs MMIC's, Si integrated circuits and microwave hybrid circuits (with discrete components or chips mounted on a passive transmission medium). The curves represent general tendencies. The frequency limits are increased by refining technology and so increasing costs but are bounded by intrinsic physical limits so that the yield falls to zero (and cost goes to infinity). At low frequencies Silicon is basically cheaper than GaAs, at high frequencies hybrid circuits have more performance. It is therefore always necessary to examine in detail the points X and Y for each application and compare all the different aspects which affect these points before being able to assess the potentiality of MMIC's.

The next chapters will deal with the first question; an examination of application areas, then the second question, a critical appraisal of present day technology. Some conclusions will be drawn by a critical appraisal of the all important question of cost and production yield which in the final analysis is what will count for consumer applications.

APPLICATIONS

A survey will be carried out on the main applications envisaged at the moment for MMIC's. The areas are television receivers, telecommunications and instrumentation. Other less well defined applications that might become interesting are considered at the end of this section.

Television reception

Two main areas are particularily promising for GaAs MMIC's, satellite receivers at 12 GHz and digital television.

12 GHz TVRO's

As we are approaching the time when satellite television will become a reality the plans are being defined in more detail.If one studies the general situation in the last two years (3, 4) one can see that more people are planning satellites for TV direct broadcast, that the time scale is still ≈ 1985 but that the economical justification for going monolithic is not clear (fig. 2) (this application is near point Y in fig. 1). Some dates that have been proposed are Canada 1984 (with Anik) USA 1985, Europe 1986-9 (Ariane, H-Sat; France, Germany, England, Italy, Switzerland, Sweden), Japan 1984 (B S-2).

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A fundamental question which will be answered differently for each country is what proportion of the population will receive by cable and how many individually.

If individually, there is a general concensus of opinion as to how much the first receivers will cost, that is about 500 $ (4)(dish, outdoor unit, indoor unit and installation costs). This is dictated more by what the customer is being offered and therefore the market quantities then by how much the receivers actually costs. This figure however seems to be reached by a hybrid approach (5, 6) in which case de MMIC solution would be for a 2nd generation maybe by using discrete chips for each function. Such chips are being proposed at the moment particularly for the RF amplifier or an UHF amplifier (7, 8). The advantage of such a conception would be that it could lend itself to a modular approach, allowing different versions for different LO frequencies, amplifier noise figures, systems (cable or otherwise), IF bandwiths, etc. I think it will be necessary to analyse the market after the system becomes operational before being able to define such a modular MMIC approach.

Digital Television

The situation for digital television or sound broadcasting is quite different. New digital systems are being developed for home video/audio systems which will radically change receiver architecture in the near future (9). This application is quite well satisfied by Si circuits (point X on fig. 1) except for some analogue processing (tuner, synthesizer, mixer, IF amp, demodulator) and GaAs could be used for these functions. Two Japanese firms are actively working on such circuits. The quantities here are perhaps more interesting than TVRO units since all TV sets will eventually be digital.

Telecommunications

Generally, this is quite a different market from that considered above for TV, quantities are small, performance is high. This does not mean that Radio Links are not interested, but they are very close to the Y point, pushing hybrid circuits to their limits in power, intermodulation etc. The comparative moderate data rate they use, can be treated in base-band by Si circuits (140 Mb/s is sufficient for most systems). G.bit rates are being considered however for some data transmission and wide band satellite systems (localisation, data banks, etc).

The interesting applications will come with optical communications however, the high data rates (10) and technological compatibility such as high input impedance and low noise preamps (11), make GaAs MMIC's a natural choice. The quantities are also important as bidirectional video transmission is envisaged to replace the telephone in such systems (12). Later still optical integrated circuits might become important enough to require big quantities.

Instrumentation

In general, instrumentation requirements are very stringent (very vide bands, low noise, low intermod, etc). Circuits are comparatively low cost but quantities are moderate. The importance attatched to GaAs IC's improved performance is evident by the interest of the two major firms in the subject (13, 14), for syntheziress, counters, etc.

For MMIC's, the situation is a little less clear but a new and potentially important area might well change this situation. This is in I.C. testing. New and faster Si IC's will need very high speed sophisticated circuitery to test them. As the rate of increase in the market is at least 25 fold over the next 10 years it will be essential to develop new equipment to cope with high speed probe stations and functional testing processors.

Other applications

Possible fields are sensors (burglar alarms, automobile circuits, industrial processes) which use or will use microwaves. They are as yet not sufficiently defined (or cheap) to include as definate contenders, but this situation might change quickly as circuits are introduced for other applications.

CURRENT STATUS OF TECHNOLOGY IN MMIC's

Recent surveys (see for example Pucel (2)) show different technologies on a more research basis. The technology is inspired by discrete FET device technology (15) or by logic IC's (16). A general tendency is that more definate technologies are freezing out and are in general use. The basic material is made by vertical pullers by the Czochralsky method with a liquid encapsulant (B_2O_3) and 2 or 3 inch diameter ingots are pulled. Ion implantation is generally used to form the active layer. The high quality and uniformity of these two processes (17) are the most critically important parameters for all applications and especially commercial ones with large quantities (18). Specific MMIC processes include the use of thick metallisation, air bridges and via holes. The development of low noise transistor techniques is a prerequisite (19) for MMIC's and these generally determine the overall production yield and the feasability of production in large quantities. A survey of different techniques is given in the references (20). What must now be defined is what mass production technology is needed to be developed (batch handling, automatic measurements, CAD tools, packaging, etc).

CONCLUSIONS

In conclusion I would like to return to Fig. 1 to what must be the overriding factor in determing whether MMIC's can be considered for commercial applications, namely the cost per circuit for a given performance. For this to be low, there must be a high production yield over a big surface. At least 3" wafers for instance must be used with MMIC's as the density is comparatively low. The lowest cost is a function of how the whole system (front end for instance) has been subdivided into different chips and the density of catastrophic faults in each layer.

It is necessary to fully evaluate statistically each technological step before topological implanting of the circuits and conception of the system can be considered. We shall be ready to answer the question in the title only after we have completed the technological development but the prospect for success are very high.

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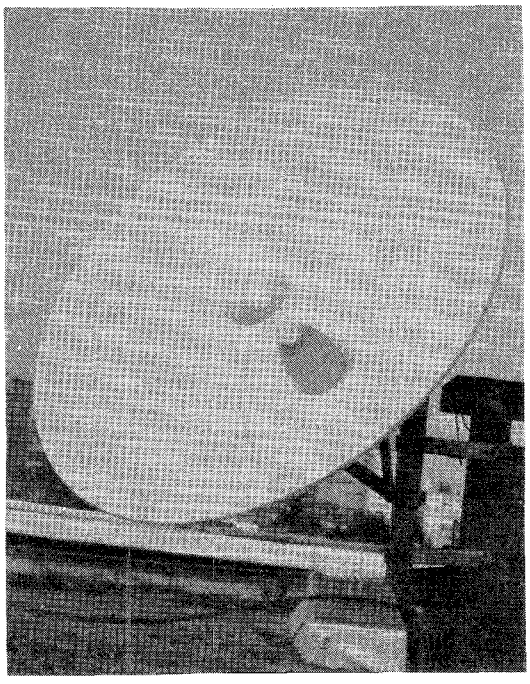

SAT TVRO DOMESTIC RECEIVERS
HYBRID OR MONOLITHIC ?

(The 70 cm dish and front-end of
THOMSON BRANDT)

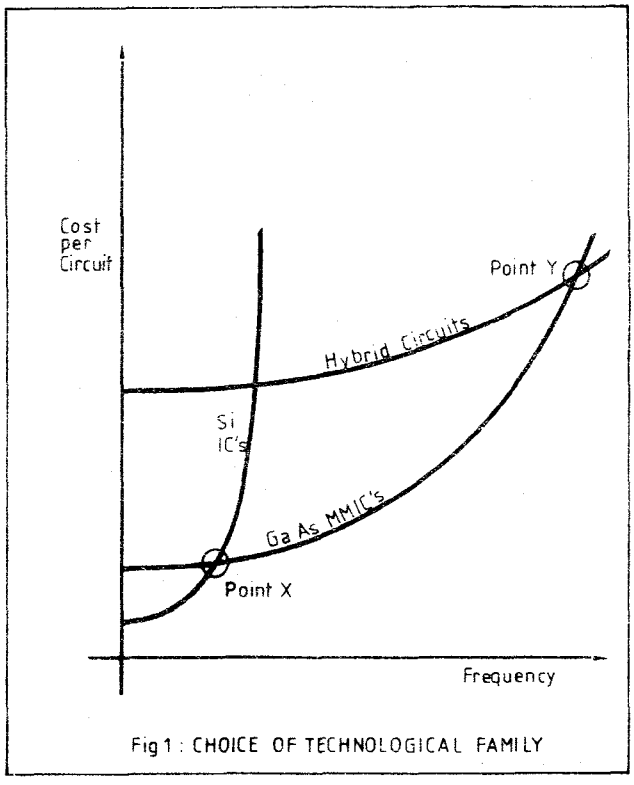

Fig 1 : CHOICE OF TECHNOLOGICAL FAMILY