

# Microwave and Millimeter-Wave Monolithic Circuit Technology, Its History and Future\*

(Invited Paper)

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## Abstract

On the tenth Anniversary of the Microwave and Millimeter-Wave Monolithic Circuits (MMWMC) Symposium, it is appropriate to review the history of the symposium and in particular how it has reflected significant technological progress over the past decade. Work reported at past MMWMC symposia will be utilized to highlight the technology advances. Emphasis at previous symposia has been on demonstrated circuit data from research performance results through early integrated component production.

Work that preceded the first of the MMWMC symposium had led to workshops at the annual Microwave Theory and Techniques Society (MTT-S) Symposia. These early MTT-S technical workshops, resulted in significant support from key MTT-S members which led to the creation of the MMWMC Symposium sponsored by MTT-S and collocated with the annual MTT-S Symposium.

The MMWMC Symposium leadership has included a broad and changing composition of professionals in education, research laboratories, and both small and large industrial firms. Results of their efforts have been reflected in the attendance of a sizeable professional community whose willingness to actively participate, submit papers, and share technical results, has created a very successful annual Symposium. This paper will recognize the contribution of numerous individuals who have contributed to that success.

For many in the microwave field, the changes that have occurred during their professional careers have been very

dynamic. From an era when it was rare for a microwave engineer to have experience with 3-terminal semiconductor devices, we now find semiconductor device physics, modeling, and computer aided design and test routinely used by microwave and millimeter wave component specialists.

The state-of-the-art presented at the Symposia meets the needs of many system requirements, and industry has demonstrated the capability to support them. Solid-State active element phased array radar development played a key role, and still plays a major role, in the advancing the technology. Yet the microwave millimeter wave monolithic circuits industry production capacity has yet to be significantly utilized for active-element phased array radars, despite sizeable investments. While the debate no longer centers on capability, it has now become an issue of timing and acquisition cost. The advantages of microwave solid-state phased array radar proposed decades ago can be achieved, but less clear is the estimate of when radars will be acquired and in what production quantities.

Modern tools required to support new technology have advanced steadily. The quality of starting materials, sophisticated processing technology, computer aided device and circuit modeling for design are currently at a high stage of development. Test equipments so necessary for efficient production, are now also available. Microwave measurements on wafers are routine, and measurements capability for microwave power device evaluation will soon be regularly found on production lines. Packaging in recent years is being addressed to achieve lower microwave components costs. The progress of these developments are all found in the MMWMC Symposia digests.

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Reported in these digests are the achievements, and to a lesser extent the mistakes and false starts that always plague an emerging technology. One of these problems, often mentioned in discussions and side meetings, has been the excess production capacity that exists. Noticeable in the digests are reports on work at companies no longer in existence. This problem will continue as existing facilities are motivated to process larger-size wafers. Ultimately, production requirements will be defined more clearly and self-correcting measures will occur.

The DARPA Microwave/Millimeter Wave Monolithic Integrated Circuits (MIMIC) program has greatly enhanced industry capability and has been described at past Symposia. Another invited paper this year will discuss the current status and emphasis of the MIMIC program on near-term insertion of technology into advanced military systems.

Much like the development of the silicon digital integrated circuit industry, there is a need to develop a large orderly commercial market. This MMWMC has recorded ongoing efforts in the development of microwave monolithic circuits for commercial application. Another invited speaker will specifically address this symposium from the perspective of the development of a commercial market.

Predicting the future trends of microwave and millimeter-wave monolithic integrated circuits is of course speculative, but the trends reflected in past symposia may be indicative of the future. The monolithic microwave circuit industry has certainly changed the whole microwave industry. The needs of the military are currently being addressed and significant opportunities in the commercial market place are developing. With the potential demand for microwave monolithic circuits in the communication, broadcast, and automotive industries, future changes can be anticipated. A new MIMIC-like program may be required to again ensure availability of monolithic microwave circuits for military applications. Exceedingly high-risk ventures seeking to establish factories of the future with highly automated capability to serve both commercial and specialized military needs may further influence the microwave industry.

The technical program of the this tenth MMWMC Symposium follows the tradition of chronicling the extraordinary advance of integrated semiconductor circuit technology into the microwave industry. Technical achievements reported in the past decade predict an exciting, challenging, and productive future.