THE STATUS OF T/R MODULE DEVELOPMENT IN THE USA

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ABSTRACT

Work on the development of transmit/receive (T/R) modules for military and commercial active array applications has been going on in the United States since the 1980s. The major goals were reduced cost, increased power, and improved efficiency. Over the last several years, significant progress has been made in these areas. For the first fifteen years, there were at least six companies aggressively pursuing this technology—both on company funds (i.e., profit dollars), and government contracts. Because of the recent mega-mergers that have occurred in the United States aerospace industry, significantly fewer companies and support are being dedicated to this technology.

This paper gives a historical account of T/R module development in the U.S. Initially, it was the military applications that drove the technology, but as time progressed, it became the commercial applications with their higher quantities that ultimately resulted in the current lower cost, high performance modules.

INTRODUCTION

In the early 1980s, the major emphasis was on MMIC technology, T/R module manufacturing technology, and reduced cost, as these were key to significantly improved T/R module and radar performance. Initially the modules were built with discrete devices, which was acceptable at lower frequencies. However, as frequency increases, MMIC technology is necessary to meet the high performance antenna requirements and the integration of RF functions into a smaller footprint. This resulted in reduced module size and lower levels of complexity, which ultimately led to lower cost and ease of assembly.

In the 1980s, military applications with required high performance requirements, complicated manufacturing, low quantities and high costs drove the technology. In the last ten years, commercial applications with their high quantity needs are driving the industry to learn how to manufacture T/R modules with high performance at low cost.

This paper gives an overview of the development of T/R modules over the last eight years in both the military and commercial markets.

T/R MODULES

Figure 1 is a collage of modules that have been developed over the past eight years at Raytheon Systems Company. The figure includes an example of a quad-pack, a side-by-side transmit and receive module, modules using low temperature cofired ceramic (LTCC) as a substrate, and a module using flip chips.

A quad-pack X-band T/R module is shown in Figure 2. This module was designed in 1990, had 4W of output power per channel, and was the first module designed by Raytheon that had its own computer on the module. At this time, it was thought that economies of scale and reduced cost could be realized by the manufacture of 4, or 8, or 12 modules combined into one housing. This was a first step in that direction. It was later learned that costs were actually higher with multiple channels per module, especially if there was any type of failure.

Figure 3 shows a two-package approach to module manufacturing that was done at the suggestion of General Motors' Delco Division. They recommended this approach as a way to reduce component count and increase reliability. This was the first module Raytheon built on automated machinery at H E Microwave. It was also the first module built with planar interconnects and flip chips.

The module at the bottom is the same module as above but contained in one package.

A 4W X-Band module with transmit and receive channels built side by side as shown in Figure 4. The receive path has an LNA, Phasor and VGSA in three parts, that are all flipped. These modules were produced at the rate of 250 per week on an Air Force sponsored contract in 1993.

Figure 5 is a photograph of a broadband X-band T/R module. This was one of the first high rate production modules produced at Raytheon. Several thousand of these modules were produced in 1995-1996.

The module shown in Figure 6 is an example of an advanced low cost module. Its dimensions are approximately 21mm x 58mm. It generates 8W of power at X-band and has a multilayer aluminum nitride (AlN) substrate with all flipped chips, and planar interconnects. It is hermetically sealed with an inexpensive dome lid, and the AlN substrate forms the bottom of the housing.

Figure 7 shows a C-band T/R module produced by ITT on an advanced airborne development program. More than 500 of these modules were produced that met or exceeded the required specifications. ITT used its Multifunction Self-Aligned Gate process (MSAG) to produce the GaAs chips for this module. The module output power was greater than 13W, and power added efficiency (PAE) exceeded 31%.

The T/R modules produced for the Iridium program (Figure 8) are manufactured by Raytheon in Quincy, MA. To date, more than 33,000 of these L-band 11W modules have been produced. The MMICs were manufactured using 0.25 micron PHEMT technology. Iridium is a 66 satellite global wireless communications network that will allow subscribers to communicate using hand-held telephones and pagers virtually anywhere in the world. Iridium, based in Bermuda, is a joint venture of Motorola, Sprint, Veba (Germany), DDI (Japan), Barkie Communications (Indonesia), and others.

Northrop Grumman manufactures X-band, and Ku-band modules at their Baltimore facility for some Air Force airborne radar programs. They have the capability of producing 4,000 modules per month in their 15,000 ft^2 facility.

The Globalstar modules shown in Figure 9 are produced by Raytheon. To date, 3,800 L-band and 5,600 S-band modules have been produced. The S-band module produces 5W of power at 2.5 GHz, and has 50 dB of gain. The Globalstar system will have 48 low earth orbit (LEO) satellites and 50-75 ground stations located around the world. By the end of 1998, they expect to have 44 or the 48 satellites plus 8 in-orbit spares launched. The system is designed to permit people to make or receive calls using hand-held, vehicle-mounted, or fixed site terminals. Globalstar is a partnership of Loral Space & Communications, Qualcomm, AirTouch Communications, Alcatel Alsthom, Alenia SpA, China Telecom, Dacom, Daimler-Benz, Elsacom, France Telecom, Hyundai, and Vodafone PLC.

SUMMARY

This paper has described many of the T/R modules that have been manufactured in the United States over the past 8 years. The modules are used in various commercial and military systems covering L-, S-, C-, and X-band applications. Also, various approaches to T/R module manufacturing were discussed, as well as why single channel modules are preferred over multiple channel (i.e., quad-pack) modules.

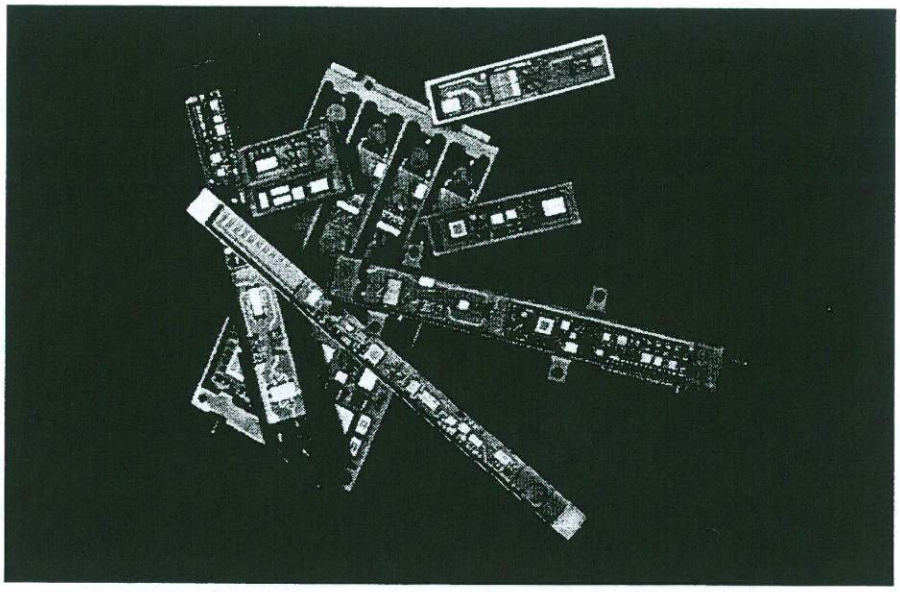


Figure 1. Transmit/Receive Modules - A Decade of Development

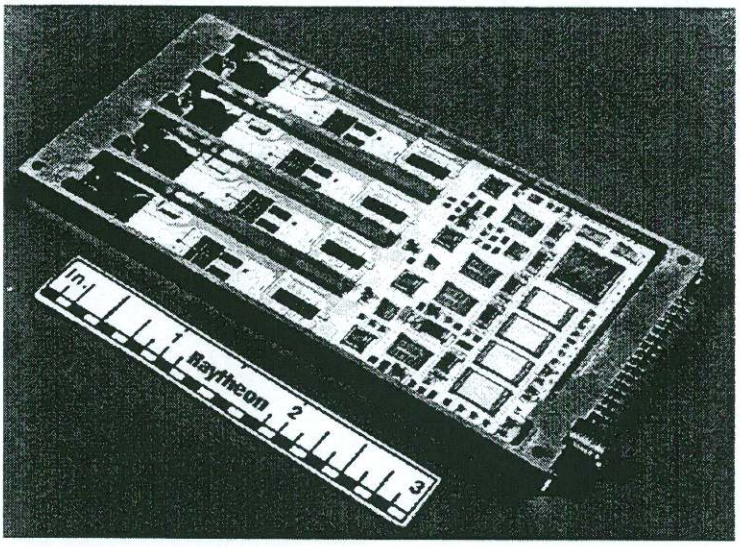


Figure 2. 1990 4-Channel T/R Module

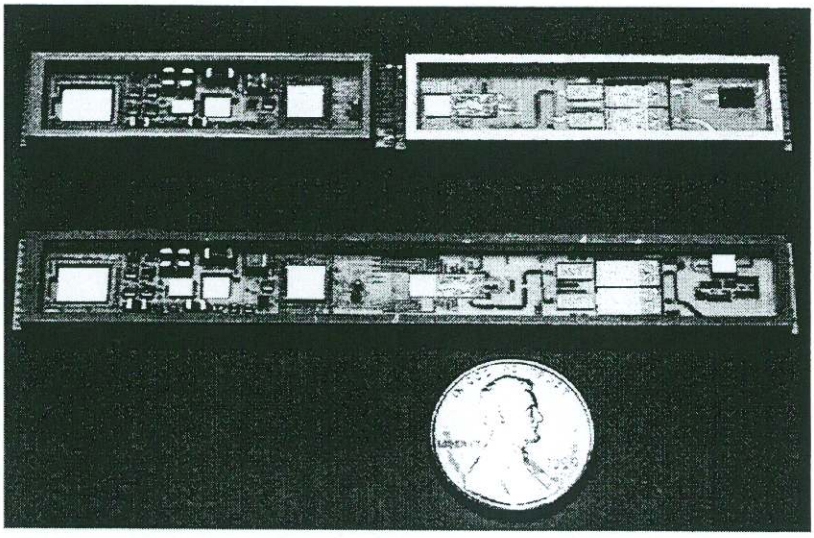


Figure 3. Raytheon Mantech T/R Module (HE 1)

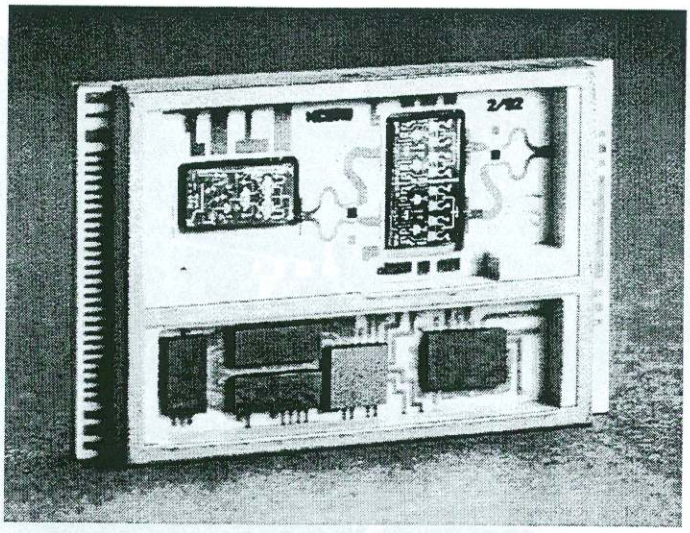


Figure 4. Raytheon Mantech Module (HE 2)

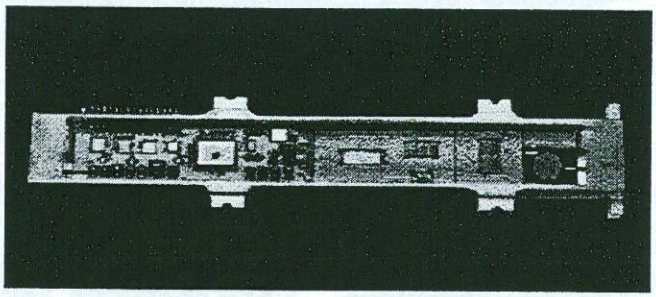


Figure 5. X-Band T/R Module

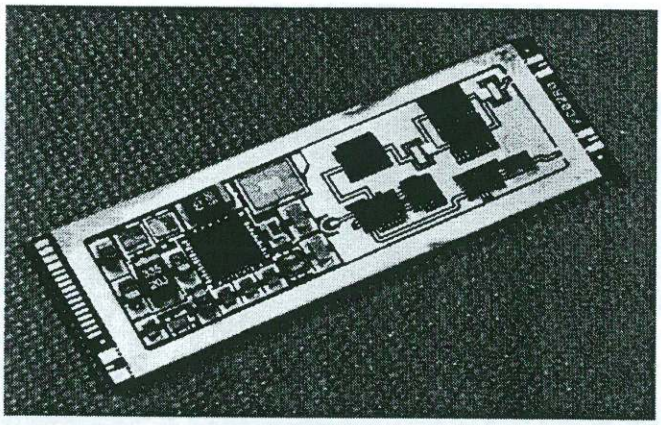


Figure 6. An Example of an Advanced Module

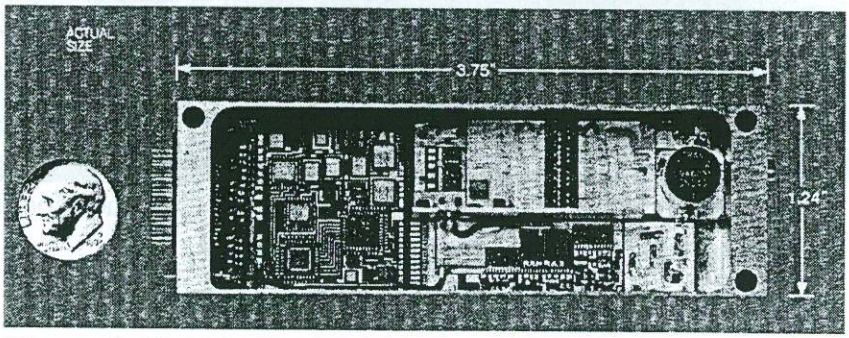


Figure 7. ITT C-Band T/R Module

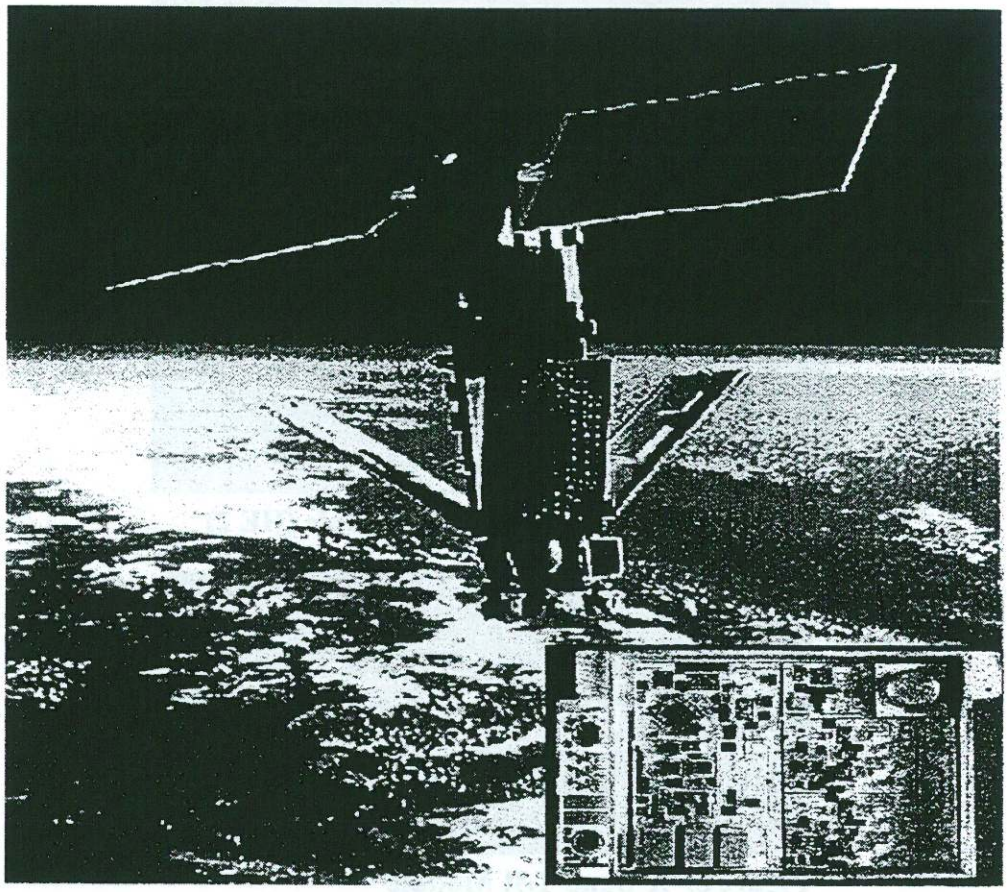
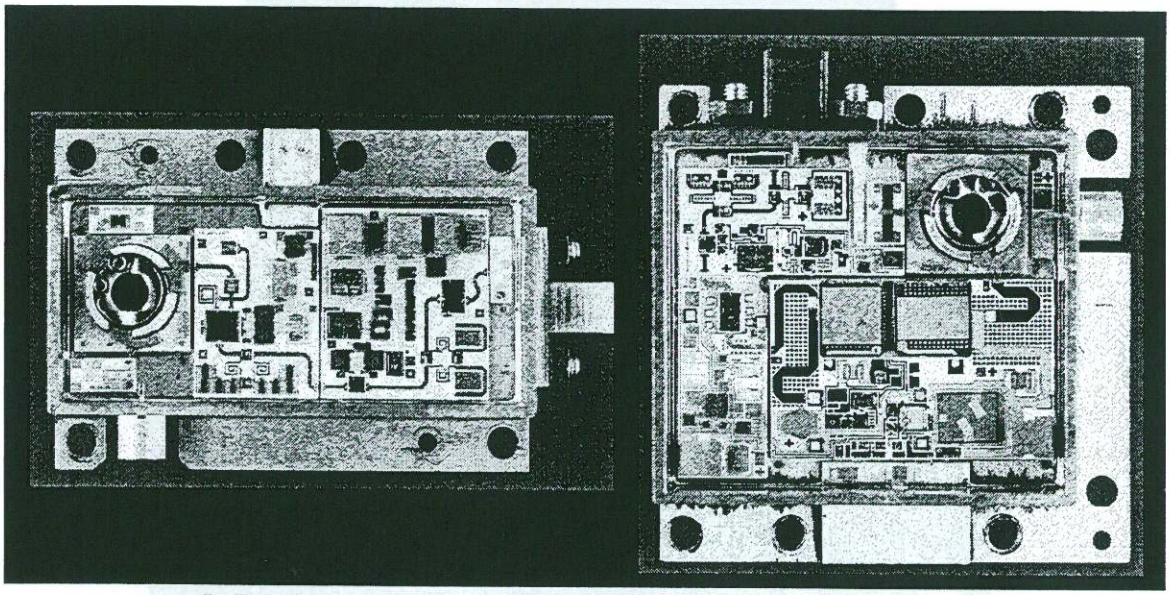


Figure 8. Raytheon's Iridium T/R Modules



L-Band Module S-Band Module

Figure 9. Raytheon's Globalstar T/R Module