# Technology Transfer of High Frequency Devices for Consumer Electronics; Concerns and Expectations

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## ABSTRACT

The aspects of high volume production on the order of millions of devices per month for consumer electronics are different from those for small and medium scale production for high-end telecommunication, instrumentation or military applications. The keys to technology transfer are also different. By investigating the examples of successful technology transfer of high frequency devices at Sony, these issues will be illustrated. The author's opinion regarding the future of high frequency devices in consumer electronics will also be presented.

## INTRODUCTION

High frequency devices have always been the key to opening new markets in consumer electronics; However, they have also been difficult to manage for both in R&D and during transfer to mass production. At the same time, it is widely understood that the consumer market can provide a strong driving force for industry and technology, as we have recently seen in satellite broadcast applications.

The majority of high volume applications of high frequency devices for consumer electronics are expected in the DBS (direct broadcast satellite) receiver and Cellular Telephone markets. DBS systems utilize the high frequency microwave range around 12 GHz, and Cellular Telephones, the lower frequency around 1-2 GHz.

Although the high frequency performance of solid state devices has improved rapidly, vast microwave and millimeter wave frequency bands are not yet developed for consumer use. Future technological advances will even open up the usage of the Terahertz range.

Also, the world can expect new high frequency engineering resources due to the relaxation of the military tension which existed between the two major powers. It would be desirable if the resources previously allocated for development of military systems could be utilized for the creation of markets in consumer electronics.

So, it would be worthwhile to investigate and discuss some of the past examples of technology transfer for consumer electronics.

## 1. HISTORICAL CASES WHERE HIGH FREQUENCY DEVICES WERE TRANSFERRED TO MASS PRODUCTION

Historical cases will be presented for investigating the key issues in transferring high frequency technology to mass production for consumer applications.

### 1-1 Transistor radio, Tunneling diode

In 1952, the radio frequency range from 500 kHz to 1500 kHz was considered to be 'high frequency' for early transistors which found limited use in hearing aids.

M. Ibuka, founder of Sony, decided to apply this technology to radios. Even though the yield was as low as five percent, he directed the company to begin mass production [1].

Lead by strong motivation and enthusiasm, remarkable breakthroughs resulted and the success opened up the age of semiconductor industry[2].

In the effort to pursue high frequency performance, the tunneling diode was invented by L. Esaki, who was then a researcher at Sony. All the effort to commercialize the device for consumer applications failed due to difficult circuit design. However, he was awarded the Nobel Prize in 1973 for the discovery [3].

### 1-2 Tuner ICs

Starting in 1974, the author and his group launched the development of mixer-oscillator ICs for VHF and UHF TV tuners [4]. The first stage amplifiers were not integrated, and the most advanced fabrication processes of the period were employed. These strategies were later justified by the fact that the volume today has reached 18 million units per year. The process has become a standard, and the resultant high frequency performance has reduced power consumption of all other very large scale ICs.

### 1-3 GaAs MOCVD (metal organic chemical vapor deposition)

In the early 1980s, laser diodes were made by liquid phase epitaxy [5], and MBE (molecular beam epitaxy) was projected for HEMTs [6]. In spite of its high productivity, MOCVD was not thought to be suitable for the production of either of these devices.

It was decided by the author and the group of N. Watanabe to apply MOCVD to both [7-10]. Today 30 million pieces of laser diodes and HEMTs are produced annually.



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Concentration on the MOCVD process was a key to the success of this transfer.

## 2. Key Factors for Successful Transfer

A few key factors for successful transfer of high frequency devices to mass production for consumer markets will be summarized.
(1) A project manager who has strong enthusiasm and clearly sees the benefit and excitement the new product will bring to society should be appointed.
(2) Demonstration of creativity is crucial and should be encouraged in identifying the new market with new technology.
(3) Engineering resources should be concentrated on selected key fields including basic research works in order to incorporate sophisticated technologies into high yield production lines.
(4) Key R&D personnel should be transferred with the product to production and marketing, because truly innovative products require new culture in which to incubate.
(5) Respect for highly skilled people should always be emphasized while their skills should be channeled into focussed programs which can be observed and improved by the group.
(6) There is critical technology to each product which must be successful to allow low cost commercialization.

## 3. Concerns and Expectations

### 3-1 New Products, New Markets

As satellite transmitted media expands, and the noise figure of the front-end devices decreases, an active phased array antenna for reception of signals from multiple satellites will hopefully excite the consumer TV market. It is necessary to provide an environment for enjoying multiple resources while paying a reasonable low price to the program supplier and copyright holder.

A simple tuner which can select from all the high frequency channels by up-conversion to microwave frequencies has long been studied, but it has not been commercialized. The advancement of solid state devices and functional devices such as YIG filters [11] may meet the requirement for these systems.

Another question might be what IC process from among those used now for GaAs MESFET[12], GaAs Junction FET[13] and HEMT will be most appropriate for GaAs mass production.

The advancement of high frequency solid state devices has now advanced to the point where one can expect exploitation of the Terahertz range. The HET (hot electron transistor) with an estimated transition time of 0.3 psec is an example [14]. In the Terahertz range, the electromagnetic waves exhibit characteristics similar to those of light, with the benefit of much easier signal handling.

The question is how a new product can be conceived in the range of such high frequencies, and how the technologies can be transferred to mass production at high yield.

### 3-2 Global scale industrial collaboration

The basic technology and the engineering resources already exist for applying the largely undeveloped microwave and millimeter wave frequencies to consumer products. For the creation of new consumer markets with new products, global scale industrial collaboration will be effective, and perhaps necessary.

It is urgent to discuss how this global technology transfer should be managed.

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