Low-Cost High-Volume RF Products: Dream, Anticipation, or Reality?

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Abstract

The analysis of several important high-volume RF product markets, such as the TVRO business, the more mature cable TV industry, and the cellular communications industry will be the focus of this work. A look at the volumes and costs of these products, as well as the RF modules comprising them, will help illustrate market demands. The role of various integrated technologies in these and future products, such as wireless cable, direct digital TV and, set-top converters will also be discussed. In addition, detailed cost discussions will focus on the "trade-offs" between hybrid and monolithic circuits, and Si versus GaAs technology. The remainder of the analysis will concentrate on the aspects of designing for low cost production and the prediction of future trends.

Introduction

The commercial microwave market has been growing explosively in recent years with some products experiencing growth rates in excess of 100 % per annum. This increase in desirability for communication products has placed stringent demands, such as cost, production volume, and time-to-market, on both the design teams and manufacturing organizations of many product suppliers.

Monolithic versus Hybrid Circuits

The overriding customer requirement in all these commercial communications systems is cost. This constraint immediately brings to the forefront the issues of monolithic or hybrid implementation, and GaAs or Si technology. The TVRO business offers a good example of the implementation of these constraints. Referring to the typical block down converter block diagram shown in Figure 1, it becomes readily apparent that the receiver chain can be implemented in a vast number of ways if cost and manufacturability were not issues. However, if the down converter is for the 3.7 to 4.2 GHz frequency range, the most expensive component in the receiver chain is the dielectric resonator, which costs less than $ 1.50. This makes it difficult for the discrete device supplier, let alone the GaAs monolithic supplier, to compete in such a low cost environment. For example, the LNA functions typically

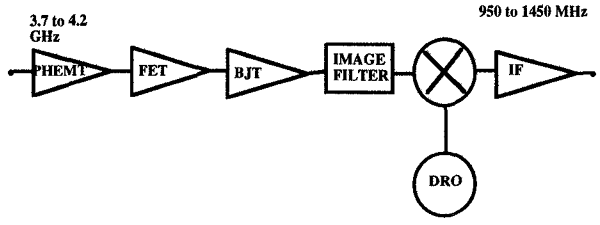

Figure 1. *Typical C-Band Block Down Converter.*

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consists of three active devices, a PHEMT in stage one, a utility MESFET or PHEMT in stage two, and a Si bipolar in stage three. Hence, the LNA function costs less than $2.00 to implement ("on shore") by using automated assembly methods employing package parts on soft substrate microwave circuit boards. The mixer and oscillator can be implemented for less than $1.00 with Si discrete devices. Typical total tune/test times for a hybrid block down converter can be substantially less than a minute. At 12 GHz, for applications such as DBS and DDS, the situation is much the same with the exception of slightly more expensive discrete FETs. It should be noted that the mixer/IF/DRO function can be implemented with a single Si monolithic IC costing about $1.00. Hence the most cost effective DDS receiver might consist of a low cost Si bipolar converter IC, a SiGe bipolar low noise amplifier IC, and a single discrete PHEMT preamplifier to set the overall system noise figure. The wireless video market is also faced with similar design trade-offs. A typical block diagram for the block down converter is shown in Figure 2.

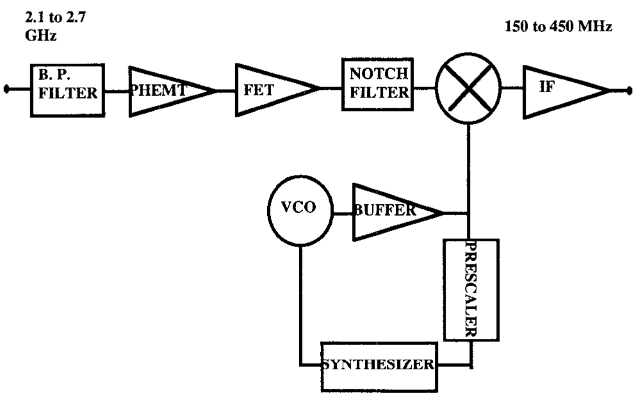

Figure 2. Wireless Video (MMDS) Block Down Converter.

Since the majority of these systems operate below 3 GHz, the benefits of GaAs over Si are much less clear. The RF converter is very similar to the TVRO/DDS receivers except the filtering is very difficult to accomplish using low cost printed techniques. In addition, these units tend to be synthesized. As in the C-Band units, the LNA function typically consists of both GaAs and Si devices, while the mixer and synthesizer components are all silicon. Silicon IC technology is an excellent candidate to realize the mixer, IF amplifier, prescailer and VCO. The RF amplifier would be difficult to implement cost effectively using any monolithic technology since the total part cost for the LNA function is about a $1.00.

The cellular market, at 900 MHz and 1800 MHz, offer some interesting possibilities for all technologies. Although the PCS market is focused on cost, small size is also desirable; thus, tilting the scale toward integration. The block diagrams for a typical digital cellular phone, is shown in Figure 3.

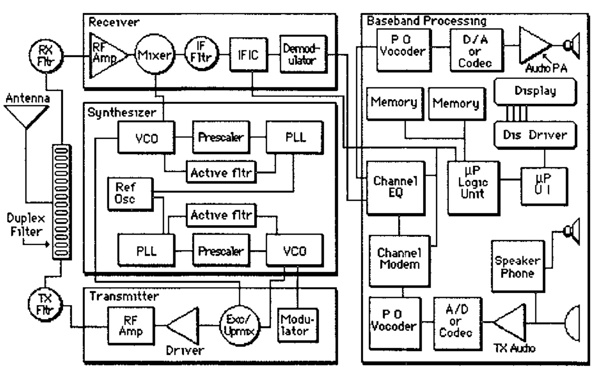

Figure 3. Digital Cellular Phone.

As can be seen in the block diagram, it appears that on the surface there is little difference between analog and digital system approaches when RF components are concerned. This assumption is not quite correct, since linearity for digital systems are more stringent. The receive chain, at 900 MHz, can be implemented with either GaAs or Si technology, with the cost/performance trade-offs being dependent on the specific application. As the operating frequency is increased to 1.65, 1.8 or 2.4 GHz, the performance advantages of GaAs become more evident. Monolithic implementations for these receiver components are becoming more favored, although there may still be a place for hybrids. As an example, for applications above 900 MHz, a discrete PHEMT first stage, in the LNA, might be needed to meet the receiver noise figure requirements. However, there is a caveat to the above analysis. New silicon technology, such as SiGe HBTs, could make the market opportunity for GaAs receiver components, just a short window in time. Similar device technology advances may have a similar impact to the transmit chain hardware complement.

At 900 MHz, the transmit chain can be conveniently and cheaply realized in silicon; however, GaAs MESFETs and HFETs are finding a place as discrete or monolithic power amplifier functions. A new silicon technology, LDMOS, has demonstrated excellent performance at cellular frequencies when used in RF power applications. The power added efficiency for both an HFET and LDMOS packaged devices, of similar overall peripheries, are shown in Figure 4.

Although the efficiency of the HFET is slightly better than the LDMOS device, it is many times the cost of the silicon device. The clear advantage that an LDMOS device possesses is that it operates from a single polarity power supply; hence no negative DC supply is required in the radio. For digital communications, PA linearity is even more of an issue than it is in analog applications. However, it is still not fully determined which technology offers the best compromise between P.A.E.,

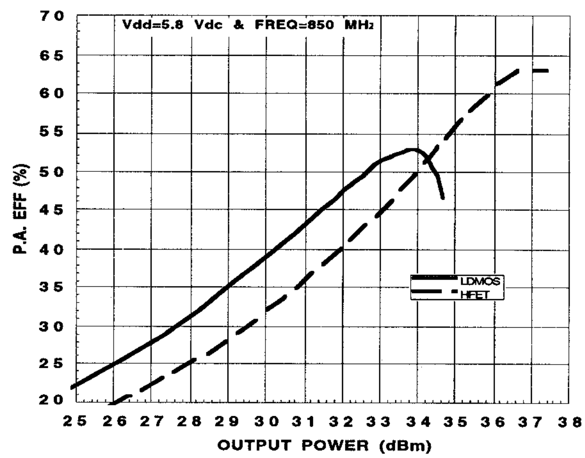

Figure 4. P.A.E. for a 20 mm LDMOS and a 18 mm HFET.

linearity and cost. It may turn out that the bulk of the applications can be served with LDMOS technology, while special applications my require GaAs HFET or HBT devices.

The other large market in which monolithic technology, for that matter GaAs technology has barely penetrated is the cable TV industry. Predominately all CATV products employ discrete Si BJT's which must be very linear. In addition to the linearity requirements, device break down voltages must be around 30 volts, which is far above most GaAs devices. The market for these products is two to three times larger than the total GaAs MMIC market. An estimate for the total available market for CATV is shown in Figure 5. It should be noted that the above estimate is for current hardware types; hence, it does not factor in the prospects of new component types which will be required to support the many new services be planned around the world. As an example, if we add some of the wireless cable business services, such as MMDS, with its projected growth rates to the established base, the market could double.

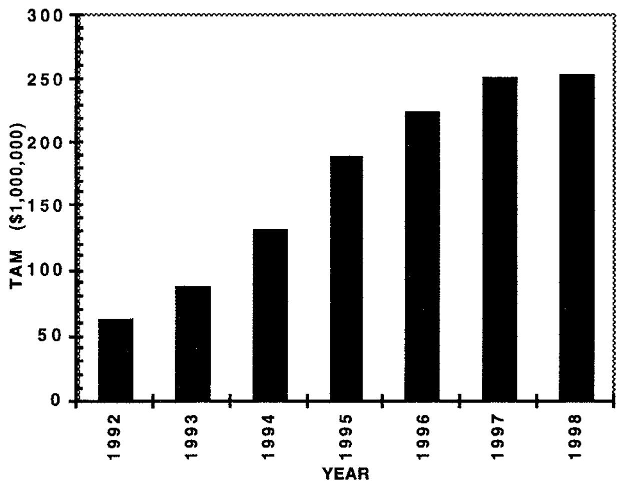

Figure 5. TAM for CATV conventional components.

Conclusion

The boom in the communications industry is apparent to everyone involved in the Si or GaAs RF device business. Unfortunately, what is not apparent is what will be the most profitable RF devices, monolithics and small components, an area where competition is fierce. Tremendous pressure is also present at the end user (consumer) part of the product chain where innovation and cost reductions are expected on a daily basis.

If one looks at the total available market (TAM) for GaAs IC's when inside sales for military products are subtracted, what remains is a relatively small market of $150 million. Although the communications business is growing at double-digit rates, GaAs IC's globally will probably not keep pace.

A good example is the TVRO business, where receiver hardware can be manufactured for tens of dollars per unit using automated hybrid circuit assembly methods. GaAs IC's will not penetrate this business unless their cost is less than the Si and GaAs discrete solution. Evan in the 12 GHz arena, Si will erode the future GaAs component share of these receivers. At 2.5 GHz and below, the exceptionally strong market growth will help the GaAs IC market segment grow, with Si still being the dominant technology.