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**Invited**

# RF Device Trends for Wireless Applications

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## 1. Introduction

The younger consumers of today primarily desire smaller and lighter wireless terminals with longer talking and standby time. RF device technologies are of paramount importance as they represent the means by these requirements can be met. Both silicon and GaAs device technologies have been pursued as solutions for use in wireless terminals. While GaAs devices have met the technical requirements, their cost is considered to be relatively high for many wireless applications. In contrast, silicon devices have found application for many of the low-tier products, but have failed to match the performance of GaAs devices. In fact, a historical pattern has emerged with GaAs devices winning the competition for initial high tier product introductions, but losing to silicon devices for higher volume and lower cost products. In the next generation of wireless systems, this pattern may or may not repeat.

## 2. Next Generation Wireless Systems

Figure 1 shows three types of the next generation of wireless systems. The first one is the IMT2000, which is characterized by high mobility and low capacity. The maximum service bit rate is up to 2 Mbps. The second one is the Advanced Wireless Access, or AWA, which is being developed in NTT [1]. This system will provide multimedia services up to 10 Mbps. The third one is the Wireless Local Loop, or WLL, which is characterized by no mobility and high capacity. Figure 2 shows the relationship between various wireless systems, with mobility as the vertical axis and information rate as the horizontal axis.

## 3. RF Device Markets

The market for all semiconductor devices was 130 billion dollars in 1996, as shown in Fig. 3 [2]. The RF device market was about 2.5 billion dollars, which accounted for only 2% of the entire semiconductor market. Silicon devices now occupy 60% of the RF device market, with GaAs device market accounting for 40%. The total GaAs device market, except for optoelectronic devices, is about 1 billion dollars, and GaAs ICs take up just about half of the total. The RF device market is considerable at 2.5 billion dollars, but it is a niche market in comparison with the whole semiconductor market.

Wireless handset sales are the primary engine of growth in the RF device market. The number of handsets for cellular and cordless phones reached 66 million units in 1996. Even so, their ranks continue to swell, and may reach 150 million units as soon as 2000.

## 4. Active and Passive Devices for MMICs

Figure 4 shows the trend of RF device cutoff frequency, $f_T$, in the 1990s. The horizontal axis is years and silicon CMOS technology size, and the vertical axis is $f_T$ in GHz. We can see rapid $f_T$ increase with MOSFET and PHEMT, but this may not be a good indication of their true potential. It may only be a reflection of researchers' enthusiasm supported by high market demand. The silicon complementary MOSFET, or CMOS, is the mainstream device of the semiconductor market. By the year 2005, CMOS technology should reach 0.1-μm dimensions with poly gates, and $f_T$ of n-MOS will reach 100 GHz [3].

MMICs consist of active devices and passive matching circuits. Since reactive (L, C, R) matching provides the best NF (Noise Figure) and PAE (Power-Added Efficiency) performance as well as higher-frequency operation, most GaAs MMICs are designed by reactive matching. In designing conventional Si RF ICs, however, reactive matching cannot be effectively used, because comparatively high conductivity of Si substrate makes it impossible to employ high Q inductors and low-loss transmission lines.

One option to overcome the high attenuation transmission lines on silicon substrate is to use high-resistivity Si wafers. High-resistivity Si wafers are readily available with resistivities above 1000 ohm-cm. These wafers permit transmission lines to be built directly on the Si substrate in the same manner as they are in GaAs circuits. The attenuation per unit length of a CPW (Coplanar waveguide) is shown in Fig. 5 [4]. By comparing the CPW lines for Si and GaAs, it can be seen that the attenuation is high for moderate resistivity silicon, but that for 2500 ohm-cm silicon is approximately the same as that of similar lines on GaAs.

## 5. Conclusions

Both silicon and GaAs device technologies have been pursued as solutions to the problems inherent in wireless applications. In both technologies, there are tradeoffs between performance, cost, reliability, and time-to-market.

### References

1. K. Ogawa, A. Hashimoto, and K. Kohiyama, "Advanced Wireless Access System," Wireless Personal Communications, Kluwer Academic Publishers, Netherlands, .4, pp..325-

問題点 ・Propagation Loss - Shadowing ⊛Multipath Fading

Loss ∝ $f^2 \cdot d^n$ (nは状況で 2~4)


338, 1997.

2. COMPOUND SEMICONDUCTOR (published six times yearly), Franklin Publishing, Saint Paul, MN.
3. P.K. Chatterjee and R. R. Doering, "Manufacturing Gigachips in the Year 2005" 1995 Symposium on VLSI Technology Digest, pp. 53-56, Kyoto, 1995.
4. G. E. Ponchak, A. N. Downey, and L. P. B. Katehi, "High Frequency Interconnects on Silicon Substrates," IEEE Radio Frequency Integrated Circuits Symposium, pp. 101-104, 1997.


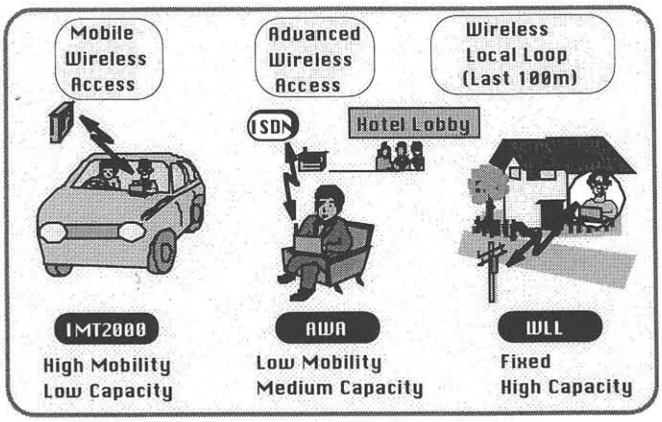


Fig. 1 Next generation of wireless systems

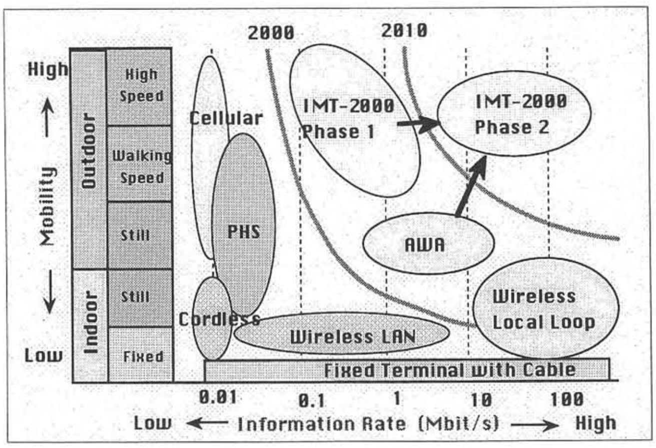


Fig. 2 Various Wireless Systems

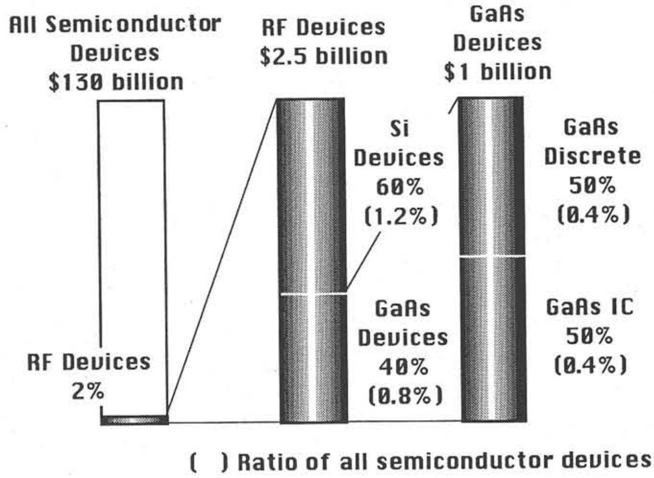


Fig. 3 RF Device Market (1996)

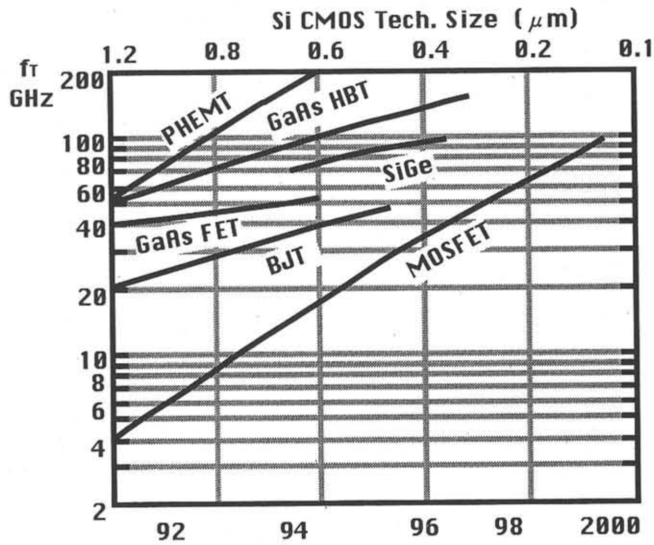


Fig. 4 RF device $f_T$ Trend

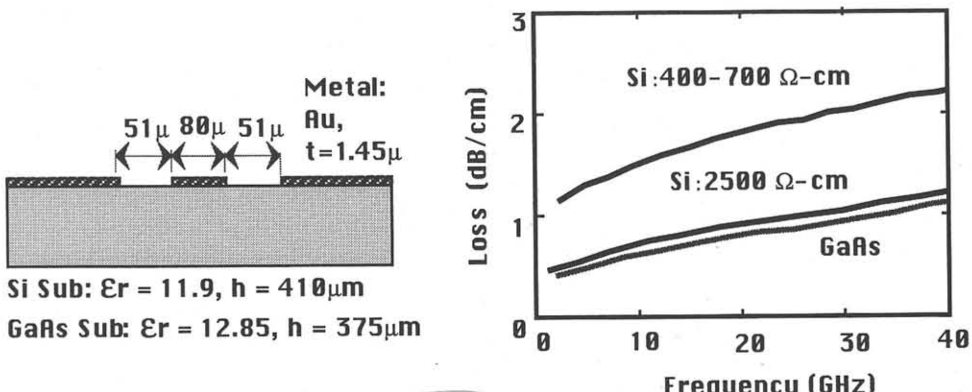


Fig. 5 Transmission Lines on Silicon Substrate

high power and high linearity

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