Low Cost 60 GHz Gb/s Radio Development

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Abstract—The recent advances of CMOS and SiGe process technologies have now made the design of low-cost highly integrated millimeter-wave radios possible in Silicon. In combination with an optimum organic Liquid Crystal Polymer packaging approach, this represents a unique opportunity to develop Gb/s radio that could address the increasing demand in term of data rate throughput of the emerging broadband wireless communication systems. In this paper we discuss the circuit and module challenges that will enable a successful deployment of 60 GHz gigabits wireless systems.

1. Introduction

The demand for ultra-high data rate wireless communication systems is increasing daily with the emergence of a multitude of multimedia applications. In particular, the needs become urgent for ultrahigh speed personal area networking and point-to-point or point-to-multipoint data link. This demand has since pushed the development of technologies and systems operating at the millimeter-wave frequencies, and overcome the current limitations of alternative solution such as 802.11n and UWB. This trend has also been reinforced by the exponentially growth of the emerging automotive collision avoidance radar applications. Indeed, the availability of several GHz band-width unlicensed ISM bands in the 60 GHz spectrum represents a great opportunity for ultra-high speed short-range wireless communications [1]. Since the mid–90's, many examples of MMIC chip-set have been reported for 60 GHz radio applications using GaAs FET and InP pHEMT technologies [2]. Despite their commercial availability and their outstanding performances, these technologies struggle to enter the market because of their prohibitive cost and their limited capability to integrated advanced base-band processing. In addition, the combination, of a low cost highly producible module technology, featuring low loss and embedded function such as antenna, is required to enable a high volume commercial use of the 60 GHz systems.

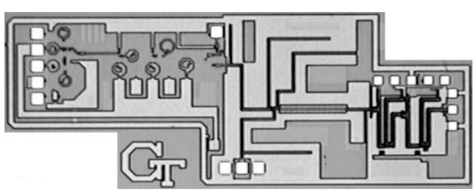

Figure 1: Photo of SiGe 60 GHz integrated MMIC.

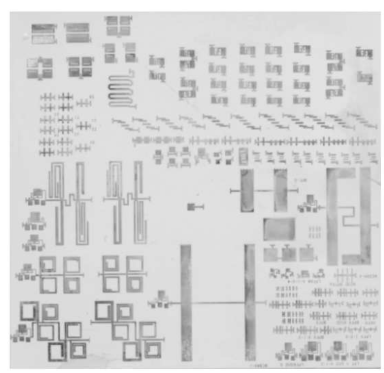

Figure 2: Photo of fabricated LCP substrate.

2. Device Technology

In this paper, we will present and discuss the advances of CMOS and SiGe technology has advanced to enable a complete chipset for 60 GHz applications [4–6]. The front-end architecture using a sub-harmonic approach will be detailed and analyzed and example of circuits such as millimeter-waves LNA, mixer and VCO will be presented. An example of integrated front-end chip that has been developed for this application is shown in Figure 1. It includes a 30 GHz cross-coupled VCO oscillating at a center frequency of 30.1 GHz and exhibiting 2.3 GHz tuning range. The maximum output power after buffer is around -11.7 dBm at 29.54GHz. The sub-harmonic APDP mixer has a measured minimum down-conversion loss of 8.3 dB with a greater than 4 GHz of single-sided 3-dB baseband bandwidth with a 5.5 dBm local oscillator signal at 30.5 GHz. An input 1dB compression point of -7dBm has been recorded. This is the first report of a 60 GHz sub-harmonic mixer on SiGe processes that can be applicable to multi-gigabit wireless personal area network application. A single stage cascode LNA has been measured to have about 15dB of gain. A 2 stages cascode LNA is under development to be combined with the others building blocks.

3. Module Technology

At last, the packaging of the 60 GHz radio represents a major challenge. The Liquid Crystal Polymer has emerged as a promising low-cost alternative for millimeter-wave module implementation [7]. It combines uniquely outstanding microwave performances, low cost and large area processing capability. It appears as a platform of choice for the packaging of the future 60 GHz gigabit radio. We will present the recent advances in developing mmW functions on LCP substrate such as filter and antennas as shown in Figure 2. The optimum combination and co-design of these technologies (Figure 1) is the key for the successful deployment of ultra-high speed, high capacity, 60 GHz WLAN access for very dense urban network and hot spot coverage. Many other commercial applications will directly benefit from this advance. This includes high data rate Wireless Multimedia Access, compact Wireless Gigabit Ethernet and Wireless FireWire/IEEE–1394 link that can be ultimately combined with a fiber or cable backhaul network.

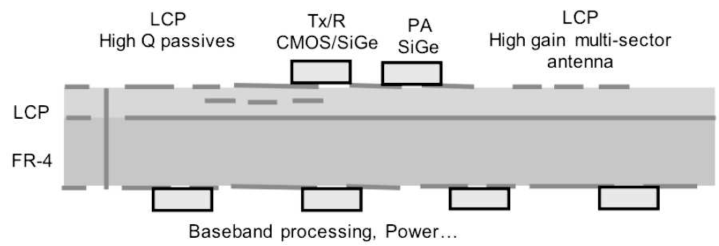

Figure 3: Concept view of a 60 GHz Gb/s radio module.

4. Conclusion

We discussed in this paper the circuit and module challenges for the next generation gigabits radio operating at 60 GHz. We highlighted the technology issues and choices based on application, system architecture, circuit and packaging considerations. The recent advances of CMOS and SiGe process technologies have now made the design of low-cost, highly integrated millimeter-wave radios possible in Silicon. In combination with an optimum packaging approach, such as a Liquid Crystal Polymer platform, these advances could have a major impact on the cost and the performances of the future high speed systems and lead a to a successful deployment of the 60 GHz gigabit wireless radio.

REFERENCES

1. Smulders, P., "Exploiting the 60 GHz band for local wireless multimedia access: prospects and future directions," *Communications Magazine, IEEE,* Vol. 40, Issue: 1, 140–147, Jan. 2002.
2. Ohata, K., et al., "Wireless 1.25 Gb/s transceiver modules utilizing multilayer co-fired ceramic technology," *ISSCC Digest*, 7–9, Feb. 2000.
3. Jagannathan, B., et al., "Self aligned SiGe NPN transistors with 285 GHz fmax and 207 GHz Ft in a manufacturable technology," *IEEE Electron Device Letters*, Vol. 23, 258–260, Issue: 5, May 2002.
4. Reynolds, S. K., B. A. Floyd, and T. Zwick, "60 GHz transceiver circuits in SiGe bipolar technology," *IEEE ISSCC Dig. Tech. Papers,* 442–443, Feb. 2004.
5. Ferndahl, M., H. Zirath, et al., "CMOS MMICs for microwave and millimeter wave applications," *Microwaves, Radar and Wireless Communications*, *MIKON-2004. 15th*, *International Conference on*, Vol. 1, No. 17–19, 247–248, May 2004.
6. Winkler, W., J. Borngraber, B. Heinemann, and P. Weger, "60 GHz and 76 GHz oscillators in 0.25/spl mu/m SiGe:C BiCMOS," *Solid-State Circuits Conference*, *Digest of Technical Papers. ISSCC*, *2003 IEEE International*, 454–507, 2003.
7. Tentzeris, M. M., J. Laskar, J. Papapolymerou, S. Pinel, V. Palazzari, R. Li, G. de Jean, N. Papageorgiou, D. Thompson, R. Bairavasubramanian, S. Sarkar, and J.-H. Lee, "3-D-integrated RF and millimeter-wave functions and modules using liquid crystal polymer (LCP) system-on-package technology," *IEEE Transactions on Advanced Packaging and Manufacturing Technology,* Vol. 27, 332–340, Issue: 2, May 2004.