A Summary of Research Activities

Research activities carried out during the PhD "Électronique des Hautes Fréquences, Photonique et Systèmes".

In a general manner a great amount of the subject discussed in this thesis is already examined in textbooks, nevertheless with the miniaturization of silicon chips new challenges to the designer engineer emerge. Passive structures that could not be fabricated in the past (inductors, capacitors, coupling structures), due to fabrication process limitations, now can be used to push forward working frequencies over and over. Also, nowadays, transistors have much higher f_T than ten years ago. This context makes it important to step back and explore design subjects on mm-waves and organize its utilization.

This work presents an overview about the design procedures on RF silicon circuits for mm-waves in silicon. Layout development is discussed and a description of how to design reliable layouts for mm-waves is presented with details on circuit simulation.

In this works, the history, development, and performance of resonator rings are also presented, specially for the use with mm-waves on silicon for filtering purposes. Two designs are proposed, as a resonant filter for 60 GHz signal waves. The first version is an octagonal filter with -3 dB of insertion-loss. The second is a meander ring with the same IL, but 60 % less area. Further, a co-design environment using EM simulation for the feed-lines coupling is presented. Although these structures are not state-of-the-art *per se*, their overall performance are compared to what is found in literature, and instigate further investigations.

Another contribution of the work is the detailing of the co-design procedure, this strategy is optimized for the design of the LNA and the filtering LNA. It is shown that in a co-design methodology the design of the LNA circuit must be executed together with the choice of components, to seek the optimal performance, therefore a custom circuit can be designed to be in conformity with the system specifications. Tree LNAs were fabricated and measured. These design have met the specifications and demonstrate good performance, what validate the design procedure. Although it were not possible to measure the noise-figure, the meander version of the filtering LNA presented the same gain as in literature but with a pass-band response, what places this circuit in the state-of-the-art for this technology (SiGe:C 0.25 µm).

The contribution of this work lies mainly to the RFIC design for mm-waves. Although great attention has been given to the receptor side of the transceiver (LNA, filter and mixer), some specific aspects to the circuit design have to be taken into account. That said, as this work is driven to circuit simulations the used technology is a restriction. For example, the transistor dimensions are imposed by physical models of the technology, also the dimension of the ring resonator is limited due to the height of the metal layer between other things, and finally the power consumption is due to the technology drive currents. These limitations can

be further addressed.

Actually, there are many discussions that were opened by on this work that can gradually be investigated, for example:

1. The circuit oriented transistor parametrization for optimal performance.
2. Use of other CMOS technology in order to reduce filter dimensions.
3. Investigations on the use of small-wave theory in ring resonators.
4. Design of mm-waves VCO, and the use of distributed component devices.
5. Investigation on mm-waves mixers.
6. Investigation on adaptation networks for mm-waves mixers.
7. Investigation on distributed devices on Silicon.

What concerns to the knowledge dissemination, the principal result of this work that is still on hold due to limitations on measurements of noise figure at extremely high frequencies. Also, a work about the ring resonators is still in preparation. Complementary, this work has been discussed in two publications, as listed below:

- MARINHO, R.S.; BARELAUD, B. ; LINTIGNAT, J. ; JARRY, B. – *Conception d'un LNA à* 60 GHz *en technologie BiCMOS SiGe:C* 0.25 µm – Journées Nationales du Réseau Doctoral en Micro-nanoélectronique, 2016, Toulouse.

- MARINHO, R.S.; BARELAUD, B. ; LINTIGNAT, J. ; JARRY, B. – *Réalisation d'un LNA BiCMOS SiGe :C large bande pour applications millimétriques* – 20èmes Journées Nationales Micro-Ondes, 2017, Saint-Malo.

Finally, this work has evolved from the idea to study general aspects of system design with the receptor side of a RFIC transceiver for 5G as object. Now that 5G is first deployed, and 60 GHz deployment is pushed further, this work is still more relevant. Most information learnt throughout many iterations on circuit analysis and design, simulation and study is presented in this work.

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