

TITLE OF THE RESEARCH ACTIVITY

Silicon integrated Built-In Test Equipments (**SiBITE**)

STATE OF THE ART

In the near future we will assist to a revolution of the telecommunication, automotive, aeronautic and space industries. In the next 10 years, novel communication systems exploiting the 5G standard will be on the market. These systems will be based on the adoption of Multiple-Input-Multiple-Output (MIMO) radio terminals and active antennas with real time beam steering capability. All the frequency bands up to mm-waves will be used in 5G with the purpose to improve both data transfer rates and link robustness. In automotive self-driving and electric cars are expected while, in aeronautics, Unmanned Aerial Vehicles (UAV) and drones will be adopted, for monitoring and logistic. Finally, the space industry, will profit of cube-satellites. In all these future applications an impressive amount of miniaturized, high reliability electronic is required.

The only approach capable to guarantee for the needed miniaturization and cost issues is based on silicon Systems-on-Chips (SoC). Nano-scale CMOS, SiGe BiCMOS and SiC processes, indeed, allows for state-of-the-art integration densities of the digital sub-systems and have the capability to cover both the mm-wave frequency range (SiGe) and the high power window (SiC).

Despite to the development of modern microelectronic technologies, however, a considerable fraction of the production costs are related to the complex tests on these new radio chips. From one hand, indeed, each chip should be tested (100% coverage) in order to guarantee for reliability in critical applications like self driving cars, drones, cubesats, etc. From the other hand, the time spent for extensive tests during production and the usage of expensive millimeter-wave instruments (vector network analyzers, spectrum analyzers, noise figure analyzers, etc.) have significative impact on the final costs. It is estimated that these costs increases between 25 to 50% if the 100% coverage approach is adopted.

A possible solution to these problems is the usage of Built-In Test Equipments (BITE), i.e. of miniaturized measurement instruments, integrated with mm-wave radio, in the same Silicon (Si) chip. With this new methodology measurements can be highly automatized, no expensive instruments are needed and each chip can communicate the results of its self test via a digital interface. Furthermore, tests can be periodically repeated during operation and this allows to the customers to verify the functionality of their electronic systems during the operative life.

The present Ph.D. research aims at conceiving, designing and testing novel BITEs for future millimeter-wave radios, with a particular focus to the generation of white noise and its usage in noise figure measurements and receiver gain calibration. **This research will be developed in strict cooperation with Infineon Technologies Austria at Villach.**

SHORT DESCRIPTION & OBJECTIVES OF THE RESEARCH ACTIVITY

The primary objective of the present Ph.D. research is to develop, experimentally validate and demonstrate the feasibility of noise diodes integrated in commercial Si/SiGe BiCMOS processes and to apply them to on-chip measurement of 5G millimeter-wave receivers. In particular, the resulting noise BITE will be used to characterize the receiver noise figure and to calibrate for gain variations. The measurement principle will be based on the Y-factor method and on the noise injection approach.

Along this line there are several open problems, requiring a deep investigation. The major issues from this point of view are: i) the derivation of a compact circuit model for avalanche noise diode; ii) the determination of the stability of such a noise source in terms of its Excess Noise Ratio (ENR) as a

function of aging and physical temperature; iii) the reliability of these devices, as they operates in avalanche, a condition that is considered critical for most devices; iv) the integration of avalanche noise sources in microwave or mm-wave receivers for measurement and calibration purposes. The last points includes all the layout issues and the biasing circuitry of the noise diode. Novel and original results are expected for each of the above issues.

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